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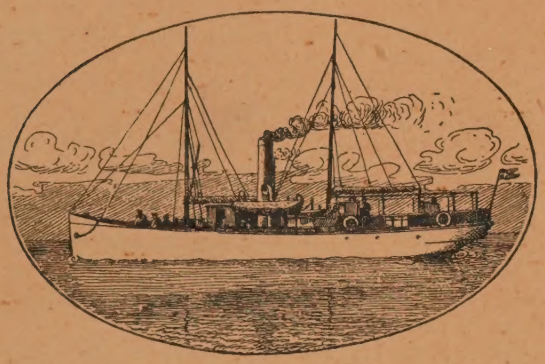
Report

of

The Danish Biological Station

to

The Board of Agriculture.



XXXIV.

1928.

By

A. C. Johansen,

Director, Dr. phil.

Copenhagen. C. A. Reitzel.

1928.

The Reports from the Danish Biological Station (Nos. I—XXI) are published in the official Danish "Fiskeri-Beretning" for the years 1890—91 until 1912. After this year they appear as special publications. The Reports I— XXXII are edited by the late Dr. C. G. Joh. Petersen.

I. *C. G. Joh. Petersen:* Fiskenes biologiske Forhold i Holbæk Fjord. (1890—91)*) 63 pp. 1 Chart. Out of print.

II. *Idem:* On the Eggs and Breeding of our Gobiidæ. (1891—92.) 9 pp. Two Plates. Out of print.

III. *Idem:* The Pelagic Life in Fænø Sound etc. (1892—93.) 38 pp. Tables. Out of print.

IV. *Idem:* On the Biology of our Flat-fishes and on the decrease of our Flat-fish Fisheries. (1893—94.) 146 pp. 2 Plates. 1 Chart. Many Tables. Out of print.

V. *Idem:* The common Eel (*Anguilla vulgaris* T.) gets a Particular Breeding-dress before its Emigration to the Sea. (1894—95.) 35 pp. With 2 Plates.
Etc. 64 pp. Out of print.

VI. *Idem:* The Yearly Immigration of young Plaice into the Limfjord etc. (1895—96). 48 pp. 1 Chart. 2 Tables. Out of print.

VII. *Idem:* Plankton-Studies in the Limfjord. 1897. 23 pp. 1 Map. 4 Tables.

VIII. *Idem:* An Otter-Seine for the Exploration of Deeper-Seas. 1898. 24 pp. With 10 Figures. Out of print.

IX. *Idem:* Trawlings in the Skager Rack and the Northern Cattegat in 1897 and 98. 1899. 56 pp. With one Map. Out of print.

X. *Idem:* List of the "Aalerusestader" in Denmark etc. — Smaller Communications. 1899 and 1900. 37 pp.

XI. *Idem:* I. The Biology of the Cod in the Danish Seas. II. On other Codfishes in our Seas. III. Some General Observations on Protection, Legislation etc. IV. Alterations and Improvements on Otter-seines for Zoological Purposes. 1900 and 1901. 44 pp.

XII. *Idem:* I. Where, and under what Conditions, can the Eggs of Plaice be developed into Young Fish within the Skaw? II. On the Young Stages of the genus *Zeugopterus.* (With one Plate). III. Can we enter into Competition with the Foreign Steam-trawlers in our Seas outside the Danish Territorial Limit. 1902 and 1903. 33 pp.

XIII. *A. Otterstrøm:* Eggs and Young of Fishes in the Danish Waters. (Investigations during 1904 and earlier years.) 1903 and 1904. 85 pp.

XIV. *C. G. Joh. Petersen:* I. The Influence of Light on the Migrations of the Eel. II. *K. I. Gemzøe:* Age and Rate of Growth of the Eel. 1906. 39 pp.

XV. *Idem:* I. First Report on the Oysters and Oyster Fisheries in the Lim Fjord. (70 pp.) 1908.

XVI. *C. H. Ostenfeld:* On the Ecology and Distribution of the Grass Wrack (*Zostera marina*) in Danish Waters. With 9 figures. 1908. 62 pp.

XVII. *C. G. Joh. Petersen:* II. Second Report on the Oyster and Oyster Fisheries in the Lim Fjord. 1908. (24 pp).

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*) The figures in ( ) refer to the "Fiskeri-Beretning" for the years quoted.

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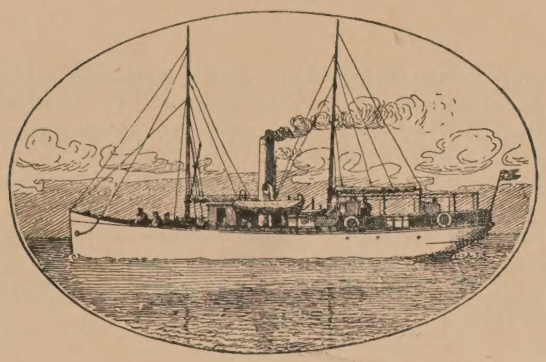

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I.

Studies on the Biology of the Oyster *(Ostrea edulis)*. V.

Further Investigations of the Fluctuation in the Oyster Stock in the Limfjord.

By

R. SPÄRCK

As has been mentioned on several occasions, attempts were made in the summers 1907 and 1924 to form a conception of the numeric quantity of oysters in the Limfjord through direct counting by means of a diver (C. G. Joh. Petersen 1908 & 1925). From the statistics of the yield of fishery, especially from those concerning the daily yield per boat per day, we may also form a more or less correct idea of the fluctuations of the stock, particularly for the years after 1910 (Lunn 1916, Spärck 1920, 1926). Directly after the last examination by diver in 1924 prohibition of the fishing of native oysters in all the part of the Limfjord north and east of Nykøbing, Mors, was instituted, so that no fishing has taken place there since the investigation in 1924. South and west of Nykøbing an inconsiderable fishing was carried out during the winter 1924—25, where upon prohibition of the fishing of native oysters was similarly instituted in this part of the fiord. This means that in the summer 1928 the stock of native oysters in the inner part of the fiord has for 3 years been left undisturbed, and in the western part of the fiord for 2 whole years. It was then decided that investigations should be undertaken in the summer in question, in order to ascertain whether these 2—3 years close time might have caused any alteration in the decrease of the oyster stock which had been going on during the years following 1922.

With our present knowledge of the biology of *O. edulis* there was not much reason for anticipating any great alteration to have taken place. It might naturally be presumed in advance that the stock of oysters would be found to be as scanty as in 1924. This further means that an examination by diver of a similar kind as that in 1924 might be expected to yield a very scanty supply of oysters per examination, and that, unless a great many examinations were made, the chances would be that accidental circumstances might play an important part. Such examinations by diver are however rather expensive and as it was only the question of forming an opinion of the course of development of the variations in the quantity of the stock, it was decided that no more than 3 diving examinations were to be undertaken, that is in the same 3 localities in which a tolerably large stock of oysters had appeared during the investigations in 1924. In the other part of the fiord dredgings were to be carried out instead, at a certain rate and for a certain space of time, so that the dredging area was in each case approximately one and the same.

By this method it became possible in a quicker and cheaper way to judge whether the stock was increasing or decreasing in quantity, and furthermore an approximate idea of its quantity per area might be deduced.

If we now turn to the examinations by diver we see that they all proved a very strong and pronounced decrease when compared with those in 1924. The 3 localities in which the investigations were carried out are: Off Flovtrup (Risgaarde Broad), off Hanbjerg (Venø Bay) and on Store Knæ west of Oddesund (Nissum Broad).

Flovtrup, depth 5 m., gravel with stones.

Size	1924 $^{27}/_{5}$		1927 $^{1}/_{8}$	
	Number of live oysters	Number of recently dead oysters	Number of live oysters	Number of recently dead oysters
6— 7 cm.	3			
7— 8 —	8	3	1	
8— 9 —	15	5	1	
9—10 —	17	5	3	1
10—11 —	6	4	3	1
11—12 —	4			
Total	53	17	8	2

Each of the two divings was carried out under quite similar weather conditions (no wind, clear sunshine); the area examined by the diver was likewise in both cases the same (about 900 m².), it was even the same diver, Mr. Chr. Ulsted of Nykøbing who undertook the examinations. It is therefore justifiable to make a comparison between these results.

Hanbjerg, 4,8 m., gravel and stones.

Size	1924 $^{18}/_{7}$		1927 $^{30}/_{7}$	
	Number of live oysters	Number of recently dead oysters	Number of live oysters	Number of dead oysters
4— 5 cm.	1		1	
5— 6 —	3			
6— 7 —	15	6	2	
7— 8 —	37	10	9	
8— 9 —	55	14	8	1
9—19 —	51	10	12	2
10—11 —	27		6	
11—12 —	1			
Total	199	40	38	3

In this case the examined area was about 700 m². ; the diving in 1924 was made in cloudy weather, in 1927 in sunshine, in both cases there was no wind. A considerable decrease appears from the comparison, exactly as in the above named case.

Store Knæ, 5 m., clay mixed with sand and gravel.

Size	1924 $^{20}/_{6}$		1927 $^{28}/_{7}$	
	Number of live oysters	Number of recently dead oysters	Number of live oysters	Number of recently dead oysters
5— 6 cm.	2			
6— 7 —	18	6		
7— 8 —	31	21	4	2
8— 9 —	40	19	5	5
9—10 —	38	14	7	5
10—11 —	10	3	2	3
11—12 —	1			
Total	140	63	19	15

The examined area was in both cases hardly 900 m². Also here the weather conditions were most favourable during the last diving, it then being sunshine, whereas in 1924 it was cloudy weather. There was no wind at any of the divings.

Thus in all 3 cases we find a distinct and considerable decrease in the stock. As to the first named locality the decrease may exclusively be due to natural mortality, no fishing having, as above mentioned, taken place there since the preceding examination by diver. After the cold winter 1923—24 the mortality was very great, the examination by diver in 1924 bringing to hand a great many empty connected shells, and as they lacked the inside growth of barnacles, annelids, etc. it may be stated with certainty that the shells had not been empty through a whole summer. On the other hand the 3 samples from 1927, especially those from Hanbjerg and Flovtrup, give proof of a much lesser mortality which is in good agreement with the mild climate of the preceding winter. The greatest decrease was noted at Store Knæ where the stock had since 1924 been reduced to $^{1}/_{7}$, at Flovtrup to between $^{1}/_{6}$ and $^{1}/_{7}$ of the stock in 1924, whilst at Hanbjerg it had decreased to $^{1}/_{5}$ of the stock in 1924. In all 3 localities the decrease thus was of the same size category. At Hanbjerg, which is beyond all doubt the locality in the Limfjord where the quantity per area of native oysters is at present the greatest, this quantity has in the course of the 3 years decreased from 1 oyster per 3.5 m². to 1 per 19 m². At Store Knæ this quantity was in 1924 1 oyster per 6,4 m²., in 1927 1 per 47 m²., and as to Flovtrup it was 1 per 17 m². in 1924, 1 per 112 m². in 1927. As regards the two last mentioned localities the quantity per area is, in spite of its particularly great frequency, below the average quantity stated in 1924 for all the fiord which was 1 oyster per 38 m². If we now consider the 3 named localities as representatives and presume that the decrease stated to be present there is also existing in the other part of the fiord, we come to the

result that the average quantity of the natural stock is of a rate of 1 oyster per about 200 m².

In order to form a notion of the quantity of the stock outside the 3 above named, more thoroughly investigated localities, some dredgings were undertaken in the different parts of the fiord. The dredged area was at each dredging almost 6.000 m².

In Livø Broad the result was as follows:

Off Trehuse	2	oysters
- Fur Hoved	3	—
- Volstrup Hage	2	—
- — —	0	—
West of Livø Tap	3	—
At Holmeflak	1	—
Blinderøn	1	—
Langegrund	0	—
Between Langegrund and Feggesund	1	—

Thus the results of all 9 dredgings agree in being a very scanty yield of oysters, only 13 in all per dredging of about 50,000 m². It must be mentioned here that the dredgings were made in localities which had formerly had a remarkable stock of oysters, and where a considerable oyster fishery had been carried out in the years 1910—20. Since 1923—24 no more dredging has, as before mentioned, taken place in the localities in question. Most of the dredgings contained 50—100 *Asterias rubens*, in a single case 125, further some *Carcinus mænas* (maximum 15); at Blinderøn and Langegrund these short dredgings resulted in several hectolitres of *Mytilus edulis*. Thus it appeared that the enemies and food competitors of the oyster were abundant.

The sizes of the 13 oysters were as follows:

9—10 cm.	3	oysters
10—11 -	7	—
11—12 -	3	—

For comparison I can state some measurements of some oysters from the same area in 1924:

6— 7 cm.	3	oysters
7— 8 -	9	—
8— 9 -	19	—
9—10 -	32	—
10—11 -	14	—
11—12 -	2	—

These numbers seem to indicate an increase in size, and at the same time the smaller groups which were, however, to a certain extent, represented at the investigations in 1924, now seem to have disappeared. This is in good agreement with the statistics of the yield of fishery which have proved that the number of small

oysters dredged together with the large ones in 1923—24 had decreased to a sheer minimum (about 5 per cent.). The 3 years close time do not seem either in this respect to have led to any result.

In good agreement with the yield of fishery being somewhat greater during the seasons 1922—24 in Risgaarde Broad and Hvalpsund than in Livø Broad, the dredgings also from these localities have better although far from fine results to present.

Off Bjørnsholm	13	oysters
Ertebølle	0	—
Risgaarde	10	—
Off Eskær	3	—
- Ø. Hegnet	4	—
Fursund	0	—

These 6 dredgings thus have yielded in all 30 oysters from an area of 35.000 m², a number which indeed exceeds that from Livø Broad, but which must, however, be considered very meagre. Also in this part of the fiord each dredging yielded up to 50 *Asterias rubens*.

The sizes of the 30 oysters found were as follows:

8— 9 cm.	7	oysters
9—10 -	13	
10—11 -	5	—
11—12 -	5	—

The oysters found at the investigations within the same area in 1924 measured:

6— 7 cm.	3	oysters
7— 8 -	12	—
8— 9 -	37	
9—10 -	46	—
10—11 -	11	—
11—12 -	3	—

From the comparison it seems to appear that the average size of the oysters of the stock, as regards Livø Broad, has somewhat increased.

In Thisted Broad the dredgings had the following results:

Feggesund	8	oysters
Skærbæk Sten	0	—
In the middle of the Broad	4	—
Off Faartoft	1	—
- Silstrup	4	

Also here there were numerous, up to 100 *Asterias rubens* in each dredging.

The 5 dredgings (about 30.000 m².) thus yielded 17 oysters, a number which is somewhat below that from Risgaarde Broad, somewhat above that of Livø Broad. The animals measured:

6— 7 cm.	1	oysters
7— 8 -	2	—
8— 9 -	1	—
9—10 -	6	—
10—11 -	7	—

In 1924 some oysters from the same area measured:

6— 7 cm.	1	oysters
7— 8 -	3	—
8— 9 -	4	—
9—10 -	13	—
10—11 -	15	—
11—12 -	9	—

No increase in the average size seems to appear from these statistics, as far as this broad is concerned; also in 1927 some individuals of the younger groups were likewise found.

In Venø Bay 3 dredgings were carried out:

Off Hanbjerg (at a somewhat greater depth than at the diver station)	4	oysters
Nygaards Hage	4	—
Kaas	2	—

By dredging at about 18.000 m² thus 10 oysters were obtained.
The measurements were:

8— 9 cm.	1	oysters
9—10 -	6	—
10—11 -	3	—

In 1924 the measurements from the same area were:

7— 8 cm.	1	oysters
8— 9 -	4	—
9—10 -	3	—
10—11 -	5	—

In Nissum Broad 7 dredgings were finally carried out:

Mullerne	1	oysters
—	1	—
Røjensø Hage	16	—
In the middle of the Broad, western part	4	—
Lemvig Røn	12	—
Nr. Nissum	12	—
Toftum	8	—

The dredging of about 40.000 m². in this broad thus yielded 54 oysters which number rather much exceeds the results from the before mentioned dredgings from other broads This also coincides with what appeared from the statistics of the yield of fishery and the examination by diver in 1924, viz. that the stock had towards the end of the fishing period 1910—25 continued relatively better in Nissum Broad than in the other broads, whilst formerly the stock seems to have been much more numerous in Livø Broad which was till towards 1920 the locality with the main production in the Limfjord.

The measurements of the oysters, dredged in Nissum Broad, were as follows:

5— 6 cm.	1	oysters
6— 7 -	4	—
7— 8 -	5	—
8— 9 -	10	—
9—10 -	14	—
10—11 -	12	—
11—12 -	5	—
12—13 -	2	—

The measurements from the same area at the investigations in 1924 were:

5— 6 cm.	1	oysters
6— 7 -	10	—
7— 8 -	10	—
8— 9 -	19	—
9—10 -	34	—
10—11 -	25	—
11—12 -	5	—
12—13 -	2	—
13—14 -	1	—

Contrary to what appears from the measurements of the dredgings in the other broads, representatives of the younger year classes are here to be seen, although in a very scanty number, compared with the older oysters. In this connection it is further to be taken into consideration that the small groups are not equally represented within the different localities. They originate from two localities, Nørre Nissum and Røjensø Hage, and in 1924 the small oyster of 6—7 cm. came from the same localities. Other localities, however, as for instance Toftum and Mullerne, yielded only large oysters in 1924 as well as in 1927. Similar observations have also been made in other places; in Thisted Broad the small oysters originate from Silstrup and Faartoft, whilst at Skærbæk Sten and in the middle of the broad only few large oysters or none, and no small ones at all were found at both investigations. From these facts it seems evident that there are certain localities in which conditions are especially

favourable to the attachment of small oysters. These few and limited localities are the only in which a little spat fall has taken place during these last years when the stock has been exceedingly small. The most prominent of these limited localities are the 3 formerly mentioned which have been examined by diver. Presumably these localities, so favourable to attachment of oysters are due to special bottom conditions, they are always found on a bottom of gravel or stones; but besides that their position leads us to believe that also currents may be of no small importance. They are most often to be found at the inner end of bays, as for instance at Hanbjerg, at the inner end of Venø Bay or behind projecting points and headlands, i. e. in places where whirlpools may be supposed to arise, causing the water to remain there most likely for a certain stretch of time, whereby favourable conditions for the attachment of larvæ are obtained. Quite similar conditions seem to be present in some other places, as for instance in the by Hagmeier and Kändler (1927) mentioned "Binnenbänke" which seem to be localities with an especially great number of young oysters, due to particularly favourable conditions of a similar kind.

Also in Nissum Broad the dredgings contained a great many *Asterias rubens*; the two dredgings at Mullerne, where the stock was found to be especially scanty, yielded 250 *Asterias* each. There may possibly be some relation between the great stock of *Asterias* and the scanty stock of oysters. In this connection it must be pointed out that oysters having been laid out on artificial beds about Mullerne, in the course of the last 15 years, and in a number of more than 10 million may very well have been contributive factors to the great number of *Asterias*.

From these dredgings we cannot, of course, deduce any precise information as to the exact size of the stock. They do, however, without doubt serve to prove that the native stock of oysters is very scanty, and that the 3 years close time have caused no increase whatever; on the contrary, the 3 more thoroughly investigated localities prove the decrease to be continued. The stock of oysters in the Limfjord has in the summer 1924 hardly exceeded 5 million, in the summer 1927 it may be presumed to have been somewhat less. The distribution of the stock within the different parts of the fiord seems to be exactly like that in 1924. As to the quantity per area of the stock it is absolutely the lesser in Livø Broad, the greater in Nissum Broad. A very small spat fall seems to take place, for the greater part limited to quite a few particularly favourable localities, and in relation to the quantity of the stock it is only very scanty.

Besides these dredgings and the counting by diver, we have one more means of forming an opinion of the quantity of the stock of oysters, that is to count the number of pelagic oyster larvæ. For this purpose and coincident with the examinations by diver and dredgings, a long series of plankton investigations were undertaken, partly in the same localities as the dredgings and the examinations by diver, partly in other places, especially in the Sounds (Oddesund, Sallingsund, Feggesund, Hvalpsund). The dredgings were carried out with a little Hensen-net, $^1/_2$ m. in diameter, which was hauled either from the bottom to the surface or at some stations also through the surface alone for a distance corresponding to the depth. These hauls

gave an enormous yield of lamellibranchiate and gastropod larvæ of different species. These organisms amounted to more than 1000 in almost each haul. Of large and more easily recognizable mollusc larvæ there were in most of the hauls at least 50 *Mytilus* larvæ, even of a so locally occurring bivalve as *Teredo* there were more than 10 larvæ in several of the hauls. Oyster larvæ were only found in two hauls, viz. at Hanbjerg where a surface haul yielded 5 oyster larvæ, a haul from bottom to surface 3, and at Store Knæ where a vertical haul yielded 1 larva. It is, most likely, not accidentally that the oyster larvæ were found in the very two localities where the stock must at present be supposed to be the most abundant. Directly before, a number of oysters, 125 in all, from different localities had been opened, 5 of these were blue-sick, so that some larvæ were to be expected in the plankton. For controlling purposes a few hundred of the Dutch oysters which had been relaid in Nissum Broad were opened, none of these however were blue-sick, which coincided with the fact that these oysters — which are much younger than the native stock of oysters in the Limfjord — had not yet begun spawning. In this connection attention must be called to the fact that, on account of the very cold spring in 1927, the oysters of the Limfjord did not start spawning until July. The results of these plankton samples thus quite agree with those of the examinations by diver and the dredgings, viz. that the stock of native oysters is extremely scanty. Formerly circumstances were of the kind that — although no systematic dredging or counting had been undertaken — at any rate a few oyster larvæ might so to speak always occur in July in plankton samples from for instance the Sounds (Oddesund or Sallingsund). So also on this point decrease prevails.

From these small investigations it seems to appear that the stock of oysters is very scanty and that there is no evidence of its increase in the course of the first years. For bringing about such an increase some warm summers are requisite, and in the first instance the increase would most probably only occur in quite a few limited localities. Not until a moderately dense stock of oysters would have occurred in these localities a sufficient production of spawn might be expected to appear in favourable years, and an increase to take place in different localities throughout the Fjord, in likeness with what was observed in 1914 and the directly preceding years.

The state of the native oyster stock in the Limfjord seems to be very much like that on the oyster beds of West Sleswig, as described by Hagmeier and Kändler, where the fluctuations in the stock as before mentioned very nearly coincide with those in the Limfjord. As regards both areas, it seems to appear with all desirable distinctness that it is impossible to carry on a considerable oyster fishing for a long series of years under our climatic conditions, without an artificial upholding of the stock through the relaying of oysters. It further seems that there is every reason to emphasize the importance of a more effective campaign against noxious animals and to prevent the localities, having proved especially favourable to the attachment of oysters, from being overgrown by food competitors; attention is particularly called to *Mytilus edulis*.

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II.

Remarks on the Hydrography of the Limfjord.

By

AAGE J. C. JENSEN

Introduction.

Up till the present the hydrographic conditions of the Limfjord have not been dealt with as a whole in the literature on the subject, and, apart from the regular daily observations of the temperature and salinity of the surface water carried out at Hals, Aalborg, Aggersund, Sallingsund, and Oddesund by the Meteorological Institute, we possess only a few isolated observations carried out prior to 1927.

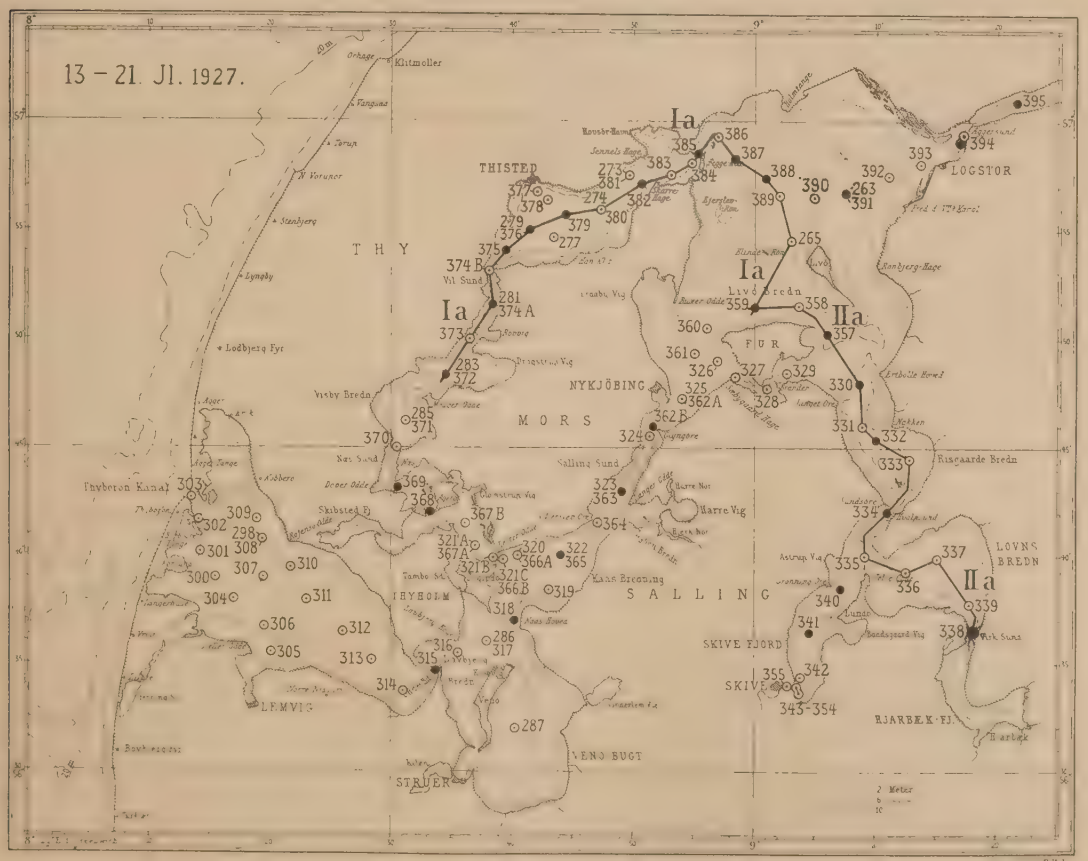

Fig. 1. Positions for hydrographical observations from July 13th—21st, 1927, in the western part of the Limfjord. (A light circle indicates surface observation, a dark circle observations from different depths.)

Fig. 2. Positions for hydrographical observations July 31st—August 3rd, 1927, in the western part of the Limfjord. (A light circle indicates surface observation, a dark circle observations from different depths.)

In the summer of 1927 investigations on the distribution of the temperature and the salinity in the Limfjord were carried out from July 13th—22nd and from July 30th—August 3rd from the Danish Biological Station's steamer "Japetus Steenstrup". The intention was to procure information on the connection between certain biological observations and the hydrographical condition in the Limfjord. From July 13th—17th surface observations alone were carried out. From July 18th—22nd and from July 30th—August 3rd observations at various depths were also carried out. All observations are given in tabular form. The salinity is in most cases determined by titration, but in some cases only by hydrometer, and is then given with 1 decimal. The determination of the salinity by titration is carried out in the Hydrographical Laboratory, Copenhagen (Professor Martin Knudsen).

Figs. 1 and 2 show the positions for the hydrographical observations in the western parts of the Limfjord (the broads).

Annual variation of temperature and salinity.

Daily observations of the temperature and salinity of the surface water have been carried out at Oddesund and Aalborg since 1893 and at Sallingsund (Glyngøre) and Aggersund from June 1910 till December 1913[1]).

The annual variations of temperature and salinity at Oddesund, Sallingsund, and Aalborg are shown in Fig. 3. For Oddesund and Aalborg they are calculated for the period 1898—1927 (30 years) and for Sallingsund the monthly mean values

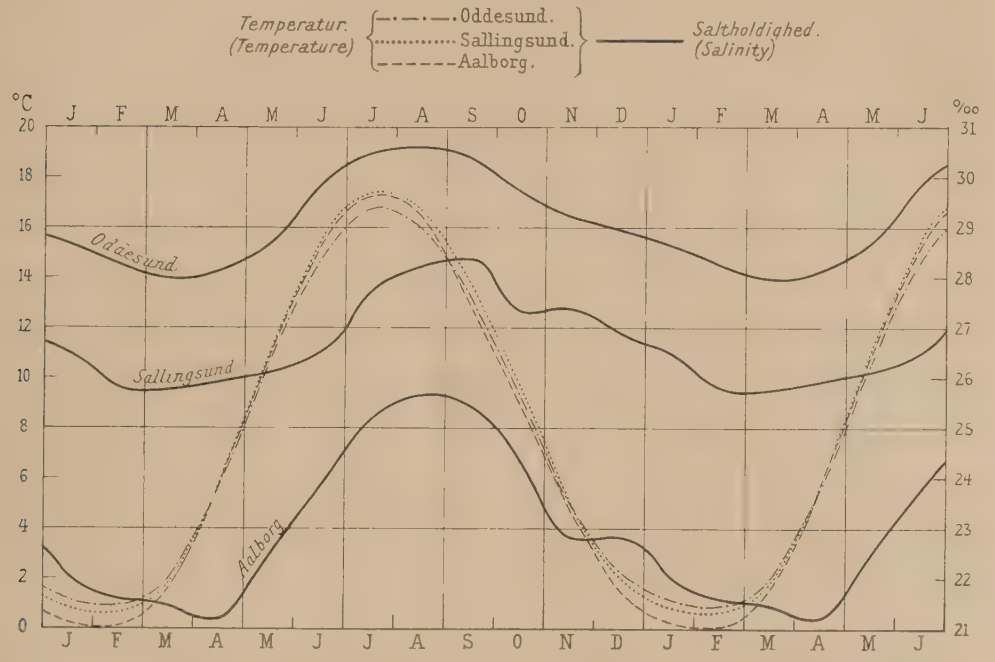

Fig. 3. Yearly range of temperature and salinity of the surface water at Oddesund, Sallingsund and Aalborg.

for the period during which the observations were carried out are corrected to the period 1898—1927 by the usual method adopted for meteorological periods of observation.

The mean temperature follows very closely the mean temperature of the air. Only during the winter months does it differ by rather more than 1° C., as the mean temperature of the surface water both at Oddesund and Sallingsund does not sink much below 1° C., whereas the mean temperature of the air in January and February is about — 0,5° C.

The mean salinity reaches its maximum in August (the curve from Sallingsund which shows the maximum in September is determined, as mentioned previously, with somewhat less accuracy than the other curves). The salinity reaches its minimum

[1]) Nautisk Meteorologisk Aarbog (Nautical Meteorological Annual) Copenhagen.

in March—April. The extent of the annual variation is c. 2,5 per mille at Oddesund and Sallingsund, but c. 4,5 per mille at Aalborg.

The annual curve of the variation of the mean salinity is quite different from that in the North Sea off Thyborøn, where the mean salinity varies in the course of the year 1—2 per mille, i. e. about as much as at Oddesund and Sallingsund, but where the salinity reaches its maximum on about February 1st and its minimum in August[1]).

The annual variation differs also from the annual variation in the salinity of the upper water layers in the Kattegat off Hals, where the salinity reaches its maximum in the winter (about December—January) and its minimum in the spring or early summer[2]). The water in the Limfjord is not in communication, owing to the configuration of the bottom, with the lower water layers of the Kattegat, where the salinity attains its maximum in May—July and its minimum in the autumn or winter.

As regards the annual average of surface salinity and the magnitude of its variation in the course of the year, the conditions in the Limfjord can be compared with those prevailing along the coast of Jutland from Thyborøn to Hals. The variation at Oddesund greatly resembles that at Skagen (the Skaw) and the conditions at Sallingsund greatly resemble those at Frederikshavn. The times of the year when the maximum and minimum are reached in the Limfjord are however, as mentioned above, about the opposite to the corresponding times in the Skagerak and Kattegat.

The annual variation in the mean surface temperature is the same as the variation in the southern and eastern Kattegat and in parts of the Belt Sea. In the northwestern Kattegat and still more in the North Sea off Thyborøn the annual variation of the temperature is less, chiefly because the mean temperature for the coldest month in the western Kattegat is c. 2° C., and in the North Sea off Thyborøn c. 4° C.

In comparison with the extent of the annual variation in mean salinity the divergences from the mean values may be large. The differences (per mille) between the highest and lowest monthly means observed at Oddesund during the years 1898—1927 were as follows:

Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
5,8	4,7	4,9	4,2	4,8	4,2	4,0	4,1	4,2	4,9	4,9	5,2

The variations from year to year of the monthly mean temperature are also considerable, in agreement with the close approximation of the temperature of the surface water to that of the air. The highest and lowest mean temperatures observed at Oddesund during the years 1898—1927 are given below, together with the differences between the highest and lowest monthly means.

[1]) G. Böhnecke: Der jährliche Gang des Salzgehaltes in der Nordsee. — Veröffentl. des Institut f. Meereskunde, Berlin, N. F. A. Hft. 17. I. 1927. pp. 18—19.

[2]) J. P. Jacobsen: Mittelwerte von Temperatur und Salzgehalt. — Medd. f. Komm. f. Havunders. Ser. Hydrografi. Vol. I. No. 10. 1908, p. 23 and charts Tafel II—V.

Highest and lowest monthly mean temperatures recorded at Oddesund during the years 1898—1927.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Highest Temp..	4,6	3,4	4,3	7,6	12,8	17,2	19,0	18,1	14,8	11,3	7,7	5,2
When observed	1898	1914	1921	1921	1921	1910	1914	1911 1917	1914	1907	1913	1898
Lowest Temp. ..	−0,5	−1,1	−0,8	3,2	8,8	11,9	14,5	13,4	11,8	7,3	0,9	−0,5
When observed	1918	1912	1917	1917	1927	1923	1898	1902	1912	1905	1919	1925
Difference	5,1	4,5	5,1	4,4	4,0	5,3	4,5	4,7	3,0	4,0	6,8	5,7

The divergencies of the salinity from the mean values can be still greater in the eastern narrow part of the Limfjord between Løgstør and Hals than in the western Limfjord (Oddesund). At Aalborg the differences (per mille) between the highest and lowest monthly means observed at the surface during the years 1898—1927 were as follows:

Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
14,3	10,9	7,7	10,7	8,7	10,3	8,9	7,6	7,6	13,3	12,9	12,7

The annual variation in the salinity seems to be determined by the quantity of water discharged by rivulets and streams. Measurements of the quantity discharged by rivulets in Jutland, which have been made by *Det Danske Hedeselskab*[1]), show that the curve of the annual variation in the discharge, with a displacement of 1 to 2 months, corresponds to the salinity in the Limfjord.

The discharge in litres per second per square kilometre from the drainage area during the years 1918—1922 has been published for four areas situated on the periphery of the Limfjord drainage area, namely, Uggerby Aa, Morup Mølleaa, Nørre Mølle Aa, and Holstedbro Aa.

The average discharge from these four localities, which may be regarded as a good expression for the influx into the Limfjord, was as follows:

Monthly mean discharge in litres per second per sq.km. from Uggerby Aa, Morup Mølleaa, Nørre Mølle Aa, and Holstedbro Aa during the years 1918—1922.

Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
19,6	16,1	14,6	11,1	8,3	5,1	5,4	6,0	7,8	8,7	9,3	13,0

It will be noticed that the displacement between the maximum discharge and the minimum salinity is about 2 months, whereas the displacement between the minimum discharge and the maximum salinity is only 1 month. As the frost in winter frequently restrains a portion of the water discharged by rivulets and streams, a larger displacement was to be expected in the winter than in the summer.

[1]) F. Techt-Hansen: Om hydrometriske Undersøgelser i Danmark. — Beretning fra Det danske Hedeselskabs kulturtekniske Afdeling. Copenhagen 1923.

Vertical and horizontal distribution of the temperature and salinity.

As is clear from Fig. 3, the mean temperature of the surface water is about the same throughout the entire Limfjord whereas the mean salinity decreases on the whole from west to east in the main passage through the Limfjord.

It has been mentioned in the foregoing that the salinity at the surface corresponds in some degree to the salinity along the shores of the Skagerak and Kattegat in that the same conditions prevail at Oddesund as at Skagen, and at Sallingsund as at Frederikshavn both as regards annual mean salinity and the magnitude of the variation of the monthly mean salinity in the course of a year. The monthly mean salinity at Aggersund is about 2 per mille higher than at Aalborg.

During the winter half-year the temperature and salinity are probably about

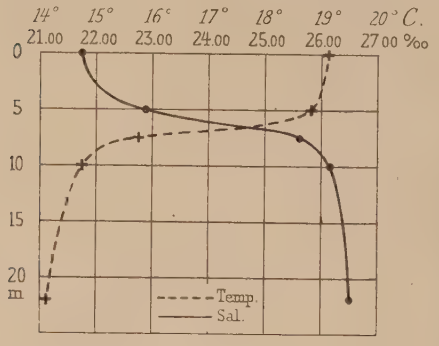

Fig. 4a. Distribution of temperature and salinity in Hvalpsund on July 19th, 1927, (St. 334).

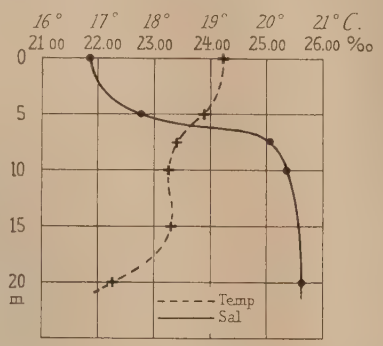

Fig. 4b. Distribution of temperature and salinity in Hvalpsund on August 2nd, 1927, (St. 536).

the same from the surface to the bottom, but in the summer half-year a stratification can frequently be found between a warmer and somewhat less salt upper layer and a colder and salter lower layer.

At the investigation on and about July 20th, 1927 there was thus found in large portions of the Limfjord a pronounced discontinuity layer, at about 6—7 metres' depth, as will be seen in Fig. 4a, which shows the variation with the depth of temperature and salinity at Hvalpsund (St. 334) on July 19th. In Fig. 4b, which shows the conditions prevailing at the same locality on August 2nd (St. 536), it will be seen that the difference between the bottom and the surface at this date was somewhat less.

Sections Ia and b, and IIa and b (Fig. 5) show the distribution of temperature and salinity along lines from Livø Broad to Thisted—Visby Broads and Risgaarde—Louns Broads respectively (comp. the charts, Figs. 1—2, p. 17, 18). Sections Ia and IIa, from about July 20th, illustrate the pronounced discontinuity layer which is to be found in the summer. Sections Ib and IIb, from about August 1st, also show some distinction between an upper and a lower water layer.

The difference in temperature between the surface and the bottom is traced on the charts Figs. 6 and 7 for all the stations from which we possess observations

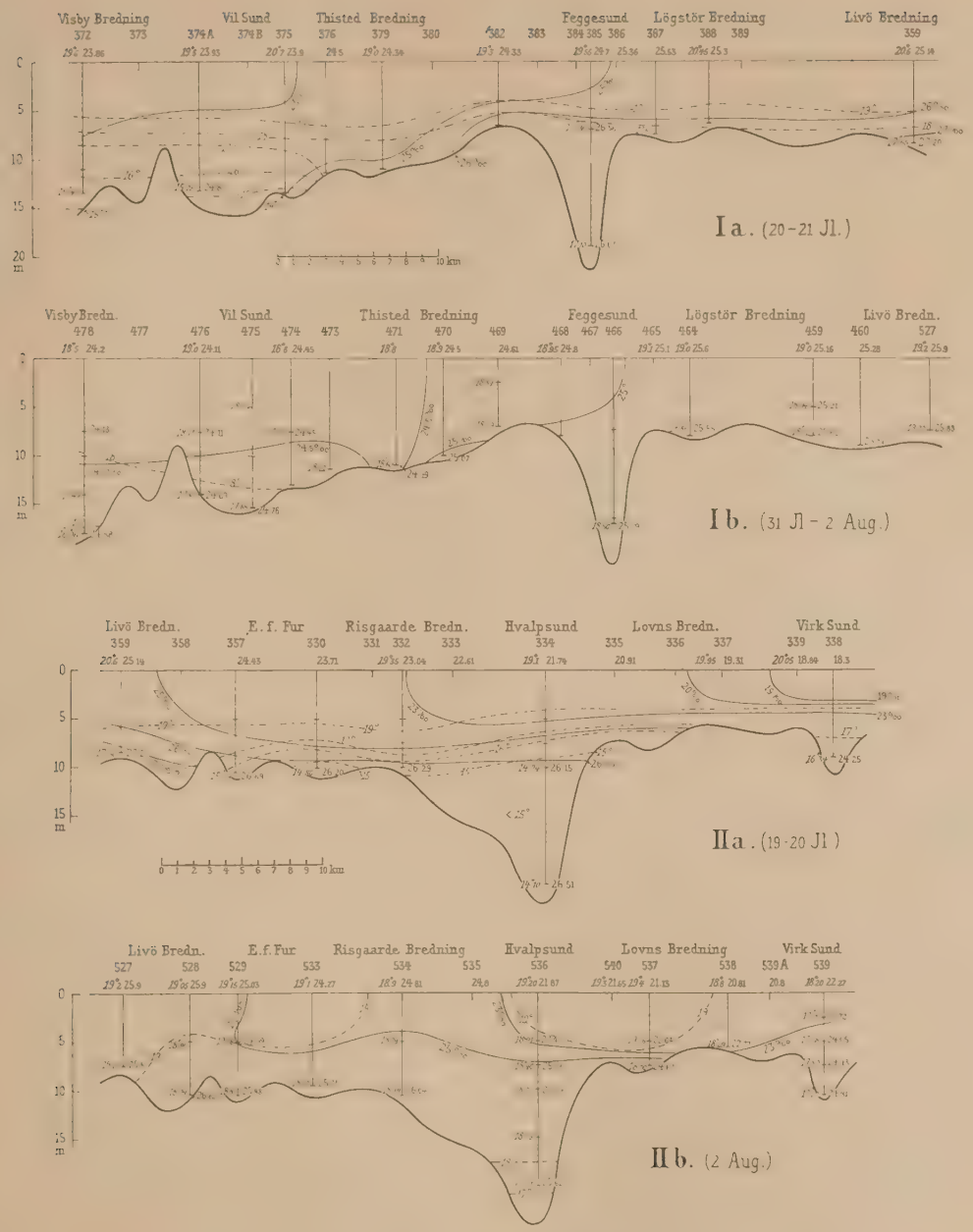

Fig. 5. Sections in the Limfjord about July 20th and August 1st, 1927.

Section I a: July 20th—21st, 1927, through Livø-, Thisted- and Visby Broads.
Section I b: July 31st—August 2nd, 1927, through the same areas as Section I a.
Section II a: July 19th—20th, 1927, through Livø-, Risgaarde- and Louns Broads.
Section II b: August 2nd, 1927, through the same areas as Section II a.

Fig. 6. Difference between temperature at surface and at bottom, July 18th—21st, 1927.

taken in the summer of 1927. It will be seen that the greatest differences in temperature were found on July 18th—21st. The bottom water in the Risgaarde and Louns Broads as in the south-western part of Thisted Broad and in Visby Broad was at this date more than 3° C. colder than the surface water. The greatest difference was found on about July 20th in Vilsund where it was 6,6° C. and in Hvalpsund where it was 5,0° C.

Some difference between the temperature at the bottom and at the surface was also found on about July 20th in Livø Broad to the north of Fur. The bottom temperature (at a depth of 8,5 metres) at St. 359 was 17,7° C., whilst the temperature at the surface was as high as 20,6° C.

A much smaller difference between the temperature at the bottom and at the surface was found at the investigation carried out on July 30th—August 3rd. The greatest observed difference was namely only 1,9° C. (in Hvalpsund) and 1,5° C. in Visby Broad. At the investigations both on about July 20th and on about August 1st the surface temperature was c. 19—20° C.

The fact that the considerable difference between the temperature at the bottom and that at the surface found on about July 20th had disappeared on August 1st

Fig. 7. Difference between temperature at surface and at bottom, July 31st—August 3rd, 1927.

must be ascribed to the force of the wind during the interval between these dates. The strength of the wind at Livø in July, 1927, is shown in the table below[1]).

Strength of the wind at Livø in July 1927 (the mean being taken of observations at 8 a. m., 2 p. m., and 9 p. m. — Scale: Beaufort 0—12.

Date	Strength of the wind	Date	Strength of the wind	Date	Strength of the wind	Date	Strength of the wind
July 1st	3,0	July 9th	3,0	July 17th	2,7	July 25th	6,0
— 2nd	4,3	— 10th	3,3	— 18th	2,3	— 26th	3,0
— 3rd	3,0	— 11th	3,3	— 19th	2,7	— 27th	3,0
— 4th	3,0	— 12th	3,0	— 20th	2,7	— 28th	3,0
— 5th	3,0	— 13th	2,7	— 21st	2,0	— 29th	3,3
— 6th	3,0	— 14th	2,0	— 22nd	2,0	— 30th	3,0
— 7th	3,0	— 15th	3,3	— 23rd	2,7	— 31st	3,0
— 8th	3,0	— 16th	2,3	— 24th	4,3		

[1]) Calculated from records on the strength of the wind kindly placed at my disposal by the Danish Meteorological Institute.

It will be seen that for more than two weeks before the investigation carried out on about July 20th there were light winds, but that the strength of the wind on July 24th—25th was considerable. During quiet weather a pronounced discon-

Fig. 8. Temperature at the bottom in the days about July 20th, 1927.

tinuity layer is thus formed in the Limfjord and especially in the more remote Thisted, Visby, Risgaarde, and Louns Broads. A short period with strong winds can however almost entirely obliterate this difference as far as the broads are concerned. In the deep channels which unite the different broads the bottom water remains less affected by mixing.

The temperature at the bottom on and about July 20th is shown in Fig. 8. It will be seen that the temperature was fairly low, under 17° C., in the deep parts of Risgaarde and Louns Broads as in the south-western deep part of Thisted Broad

Fig. 9. Salinity at the bottom in the days about July 20th, 1927.

and throughout a considerable part of Visby Broad. In the deepest parts within these areas, in Hvalpsund and Vilsund, the temperature was even lower than 15° C.

The salinity at the bottom on and about July 20th is shown in Fig. 9. It should be noticed that the salinity at the bottom steadily decreases as we pass through the main passage from west to east, and similarly (compare Sections Fig. 5) when

we pass from the main passage to the more remote broads. This continuity in the decrease of the salinity higher up the fjord is not an expression, as is clear from the foregoing, for an even flow of water from west to east since the bottom water in Sallingsund and in the largest part of Livø Broad was mixed to a fairly great extent with surface water, whilst the bottom water in considerable parts of Thisted—Visby and Risgaarde—Louns Broads where the temperature is low proves to be stagnant. It will be seen further in Fig. 7 that the salinity in the lower water layer was on the whole higher in the Risgaarde—Louns Broads, which have the open entrance from the main passage, than in the Thisted—Visby Broads which are in communication with it only by narrow sounds.

In several of the narrows a considerable difference in salinity can be met with within a few kilometres' distance. Section III, Fig. 10 which is drawn from Nissum Broad to Agerø Broad, shows this to be the case on August 1st in the sound between the latter broad and Kaas Broad.

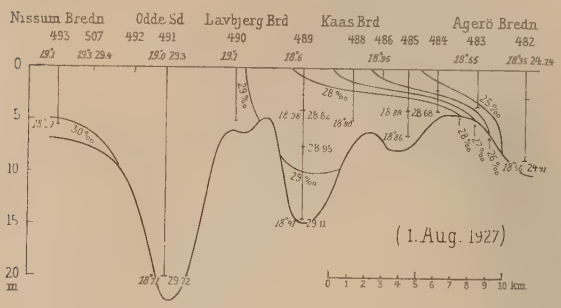

Fig. 10. Section through Oddesund, Kaas Broad and Agerø Broad, August 1st, 1927.

The low temperatures in the lower water layer which were found on July 20th in some parts of the Limfjord, show that for some time previously the bottom water in these areas of the Limfjord had been renewed to a very slight extent.

From the temperature of the bottom water, which showed a minimum of 14,07° C. (St. 375), it can be seen that the bottom water in any case had been cut off from the surface since the beginning of July, as the surface temperature (at Oddesund and Aalborg) had been warmer during this period. On July 1st—4th the mean temperature at Oddesund was 14,0° C., but from July 5th it was over 15° C. Probably however the bottom water was not renewed at this date, when the weather was fairly quiet, but during the very windy weather which prevailed during the last third of June.

The bottom water in the remote broads is thus chiefly renewed at intervals. In addition to a violent renewal such as that which took place between the 21st and 30th of July, a slow renewal caused by an inflow of water along the bottom can take place in quiet weather. Section Ia, Fig. 5 and chart, Fig. 7 show that an inflow into Thisted Broad from Feggesund of comparatively salt and fairly warm water was taking place at this time. $\bar{\sigma_t}$ for this water is namely (at St. 382) 18,74, whilst the bottom water in the deep south-western part of the broad at St. 279 shows $\sigma_t = 18{,}11$ and at St. 375 $\sigma_t = 18{,}56$. The warmer salter water in the eastern part of Thisted Broad would thus, by reason of its specific gravity, try to follow the slope of the bottom to the western part of Thisted Broad and Vilsund.

In the eastern narrow part of the Limfjord from Løgstør to Hals there seems to be a marked difference between the range east and west of Aalborg.

Salinity-observations on the 22nd and 30th of July 1927 at 3 different localities in the Limfjord between Aalborg and Hals.

Depth	c. 20 km. W. of Hals		c. 14 km. W. of Hals		c. 3 km. W. of Hals	
	57°5′ N. lat. 10°1′30″ E. long.		57°2′30″ N. lat. 10°6′ E. long.		56°39′ N. lat. 10°15′25″ E. long.	
	St. No. 409	St. No. 440	St. No. 411	St. No. 438	St. No. 415	St. No. 434
	July 22	July 30	July 22	July 30	July 22	July 30
0	22,23		19,52	19,61	16,78	20,79
2½		21,78				
7½		23,22	22,16		21,85	22,30
Bottom	22,66 (12 m.)	23,28 (12 m.)	22,21 (10,5 m.)	23,22 (9 m.)	22,21 (15 m.)	22,52 (15 m.)

In this part, to the east of Aalborg, there was found in the summer of 1927 a stratification between an upper and lower water layer, and this is probably a normal feature for this area.

On the other hand in the part of the Limfjord between Løgstør and Aalborg the salinity and temperature seem mostly to be approximately uniform from the surface to the bottom. Nevertheless in areas such as Nibe Broad, into which several considerable watercourses discharge, a thin very slightly saline surface layer may be found in quiet weather.

Table. Hydrographical observations in the Limfjord carried out from the steamer of the Danish Biological Station "Japetus Steenstrup" from July 13th—22nd and from July 30th—August 3rd 1927.[1])

1. Stations, where only surface observations are carried out.

St. No.	Date	N. lat.	E. long.	$t°\,C$	$S\,‰$
	July 1927				
263	13	56°56′40″	9°07′30″	19,0	25,8
265	»	56°54′30″	9°03′	19,7	26,3
273	14	56°57′30″	8°49′40″	19,2	24,7
274	»	56°56′	8°47′30″	18,9	24,8
277	»	56°54′40″	8°43′20″	18,9	24,9
279	15	56°55′	8°41′20″	18,2	24,51
281	»	56°51′30″	8°38′20″	18,8	23,82
283	»	56°48′20″	8°34′30″	19,6	23,80
285	»	56°46′15″	8°31′15″	19,2	23,60
286	»	56°36′	8°38′	18,8	27,83
287	16	56°32′	8°40′15″	19,0	29,02
298	17	56°40′40″	8°19′20″	18,5	30,91
300	»	56°39′	8°15′30″	18,3	30,95
301	»	56°40′15″	8°14′	15,3	31,24
302	»	56°41′40″	8°14′	15,2	31,20
303	»	56°42′30″	8°13′		31,13
304	»	56°38′	8°17′	18,0	30,93
305	18	56°35′30″	8°20′	18,4	31,2
306	»	56°36′40″	8°19′45″	18,0	30,93
307	»	56°39′	8°19′30″	16,6	31,02
308	»	56°40′40″	8°19′20″	17,0	31,00
309	»	56°41′45″	8°19′	17,0	30,8
310	»	56°39′30″	8°21′45″	18,4	30,82
311	»	56°38′	8°23′	18,2	30,86
312	»	56°36′30″	8°26′	18,3	30,95
313	»	56°35′15″	8°28′20″	18,4	30,90
314	»	56°33′45″	8°31′	18,4	30,53
316	»	56°35′30″	8°35′30″	18,9	29,42
317	»	56°36′	8°38′	18,8	29,49
319	»	56°38′30″	8°43′	19,2	28,33
320	»	56°40′	8°40′30″	19,0	28,26
»	»	»	»	19,0	27,5
321A	»	56°40′30″	8°37′	19,0	26,09
321B	»	56°39′50″	8°39′	19,1	26,1
321C	»	56°39′45″	8°39′30″	19,1	26,1
322	»	56°40′	8°44′	19,2	26,80
324	19	56°45′30″	8°51′20″	18,8	27,09
325	»	56°47′20″	8°54′	18,8	26,44
326	»	56°49′	8°57′	18,7	26,20
327	»	56°48′20″	8°58′30″	19,0	24,85
328	»	56°47′45″	9°01′	19,4	24,2
329	»	56°48′30″	9°02′40″	19,5	24,36
331	»	56°46′	9°08′50″	19,5	23,17
333	»	56°44′30″	9°12′40″	19,6	22,61
335	»	56°40′	9°09′	19,2	20,91
336	»	56°39′20″	9°12′30″	19,6	19,7
»	»	»	»	19,8	20,08
337	»	56°39′45″	9°15′	20,0	19,31
339	»	56°37′40″	9°17′40″	20,0	18,84
342	»	56°34′30″	9°03′40″	20,0	21,24
358	20	56°51′30″	9°03′40″	20,6	24,88
360	»	56°50′30″	8°56′	21,0	25,61
361	»	56°49′20″	8°55′	21,0	25,99
362A	»	56°47′20″	8°54′	20,4	26,6
363	»	56°43′	8°49′	19,7	27,5
364	»	56°41′30″	8°47′	19,7	27,6
366A	»	56°40′	8°40′30″	20,2	27,94
366B	»	56°39′45″	8°39′30″	20,2	26,6
367A	»	56°40′30″	8°37′	19,9	26,31
367B	»	56°41′30″	8°36′	19,6	25,8
370	»	56°45′	8°30′30″	21,2	23,78
371	»	56°46′15″	8°31′15″	19,8	23,82
373	»	56°50′	8°36′30″	20,0	23,78
374B	»	56°53′	8°38′	20,2	24,1
377	21	56°56′40″	8°42′	18,2	22,38
378	»	56°56′20″	8°43′	19.0	24.7
380	»	56°56′	8°47′20″	19,2	24,27
381	»	56°57′30″	8°49′40″	19,3	24,36
	July 1927				
383	21	56°57′30″	8°53′	19,4	24,58
384	»	56°58′	8°55′	19,4	24,9
386	»	56°59′20″	8°57′	19,8	25,36
389	»	56°56′30″	9°02′	20,4	25,3
390	»	56°56′30″	9°05′	19,6	25,23
392	»	56°57′30″	9°11′	20,0	25,2
393	»	56°58′	9°13′40″	20,2	24,96
395	»	57°00′45″	9°21′30″	20,5	24,88
402	»	57°03′15″	9°48′40″	21,6	23,1
404	»	57°03′20″	9°52′15″	21,9	21,6
405	»	57°03′45″	9°53′30″	21,7	22,50
406	»	57°03′35″	9°54′30″	21,5	22,3
407	»	57°03′20″	9°55′20″	22,0	21,76
410	22	57°03′30″	10°03′30″	20,0	20,34
412	»	57°01′20″	10°08′30″	20,2	20,03
414	»	56°59′	10°13′25″	19,2	17,56
416	»	56°59′20″	10°17′20″	19,3	17,74
417	»	56°59′	10°19′15″	19,3	18,44
418	»	56°58′	10°22′30″	19,2	15,32
433	30	56°59′20″	10°17′20″	19,1	21,02
435	»	56°59′	10°13′25″	19,6	20,3
437	»	57°01′20″	10°08′30″	20,0	19,7
439	»	57°03′30″	10°31′30″	20,4	13,7
441	»	57°04′12″	9°58′20″	19,4	22,95
442	31	57°03′45″	9°53′30″	19,5	16,18
444	»	57°03′15″	9°48′40″	19,2	24,1
448	»	57°01′50″	9°39′40″	19,0	23,57
449	»	57°01′45″	9°38′30″	19,1	24,81
453	»	57°00′45″	9°21′30″	19,2	24,5
454	»	57°00′50″	9°21′15″	19,5	24,6
456	»	56°58′	9°13′	19,6	23,77
458	»	56°56′	9°06′	19,0	25,16
462	»	56°54′	8°57′30″	19,0	26,9
465	»	56°59′20″	8°57′15″	19,1	25,1
467	»	56°58′	8°54′30″	19,0	24,9
477	»	56°50′	8°36′30″	18,8	24,09
480	»	56°45′15″	8°30′30″	18,4	24,2
481 a	»	56°43′	8°28′40″	18,4	24,3
	August 1927				
486	1	56°39′40″	8°39′20″	19,0	25,3
487	»	56°39′20″	8°39′30″	18,7	25,7
492	»	56°34′	8°32′40″	19,0	29,4
494	»	56°35′40″	8°27′40″	18,8	29,8
498	»	56°40′30″	8°18′	18,8	30,8
500	»	56°41′	8°14′30″	18,2	30,5
502	»	56°39′	8°15′40″	18,9	30,9
504	»	56°37′15″	8°22′10″	18,8	30,9
506	»	56°35′	8°25′30″	18,6	30,5
507	»	56°33′40″	8°30′30″	19,3	29,4
509	»	56°33′20″	8°36′30″	19,9	29,1
512	»	56°32′10″	8°40′30″	19,9	29,0
515	»	56°38′	8°41′	19,9	28,4
516	»	56°38′35″	8°42′	19,6	28,3
518	»	56°41′30″	8°47′	19,9	28,3
520	»	56°44′20″	8°50′30″	19,6	26,4
522	2	56°47′15″	8°53′25″	19,4	27,1
532	»	56°48′40″	9°02′45″	19,2	24,99
535	»	56°44′	9°13′	18,7	24,8
539A	»	56°38′	9°17′20″	18,7	20,8
540	»	56°40′	9°09′	19,3	21,65
543	»	56°35′	9°04′30″	19,2	22,07
544	3	56°43′40″	9°10′15″	18,2	24,8
550	»	57°00′50″	9°21′15″	17,8	23,98
555	»	57°03′15″	9°48′40″	19,0	24,05
556	»	57°02′50″	9°51′	19,1	23,78
557	»	57°03′20″	9°52′15″	19,1	23,60
558	»	57°03′35″	9°54′30″	19,1	23,22

[1]) Observations of salinity shown with 1 Decimal are determined by hydrometer.

2. Stations, where observations from different depths are carried out.

m	$t°C$	$S‰$
St. 315 VII 18		
56°34′40″N		8°34′E
0	18,6	30,1
22	18,33	30,43
St. 318 VII 18		
56°37′N		8°40′15″E
0	18,7	28,89
6,5	18,69	28,98
13	18,42	29,60
St. 323 VII 18		
56°43′N		8°49′E
0	19,2	27,74
10	18,96	27,74
St. 330 VII 19		
56°48′N		9°08′40″E
0	19,4	23,71
5	19,12	24,20
10	14,80	26,20
St. 332 VII 19		
56°45′20″N		9 10′E
0	19,4	23,04
5	19,30	23,57
7,5	18,49	24,88
10	15,29	26,29
St. 334 VII 19		
56°42′N		9°11′E
0	19,1	21,74
5	18,82	22,9
7,5	15,75	25,61
10	14,74	26,15
22	14,10	26,51
St. 338 VII 19		
56°36′30″N		9°18E
0	20,3	18,3
9	16,34	24,25
St. 340 VII 19		
56°38′30″N		9°07′E
0	19,5	21,08
4	18,92	22,57
6	16,54	25,07
St. 341 VII 19		
56°36′30″N		9°04′30″E
0	19,7	21,29
4,5	17,46	24,47
St. 356 VII 20		
56°50′30″N		9°09′40″E
0	19,6	24,36
7,5	17,49	25,93
10,5	15,69	26,62
St. 357 VII 20		
56°50′20″N		9°06′E
0	19,2	24,43
5	19,15	24,58
10,5	15,39	26,69
St. 359 VII 20		
56°51′30″N		9°00′E
0	20,6	25,14
8,5	17,66	27,20

m	$t°C$	$S‰$
St. 362 B VII 20		
56°46′N		8°51′40″E
0	19,6	26,35
23,5	19,13	27,57
St. 365 VII 20		
56°40′N		8°44′E
0	19,8	27,9
6,5	18,94	27,92
St. 368 VII 20		
56°42′N		8°33′20″E
0	19,5	24,63
5	18,93	25,55
8,5	18,90	26,89
St. 369 VII 20		
56°43′N		8°30′30″E
0	20,1	23,8
6	18,88	24,51
St. 372 VII 20		
56°48′20″N		8°34′30″E
0	19,6	23,86
7	18,06	23,98
11	16,56	24,4
13,5	15,47	24,45
St. 374 A VII 20		
56°51′30″N		8°38′20″E
0	19,5	23,93
13	15,28	24,8
St. 375 VII 20		
56°54′N		8°39′30″E
0	20,7	23,9
7	18,49	24,29
13,5	14,07	25,07
St. 376 VII 20		
56°55′N		8°41′20″E
0	20,2	24,5
11,5	17,17	25,32
St. 379 VII 21		
56°55′40″N		8°44′20″E
0	19,0	24,34
11	18,13	25,03
St. 382 VII 21		
56°57′20″N		8°50′40″E
0	19,3	24,33
4	19,02	25,2
6,5	17,58	26,44
St. 385 VII 21		
56°58′30″N		8°55′20″E
0	19,55	24,7
7	17,74	26,36
19	17,10	26,67
St. 387 VII 21		
56°58′20″N		8°58′30″E
0	19,4	25,53
7,5	17,82	26,35

m	$t°C$	$S‰$
St. 388 VII 21		
56°57′20″N		9°01′E
0	19,45	25,3
6,5	18,23	26,09
St. 391 VII 21		
56°56′40″N		9°07′30″E
0	19,4	25,2
6,5	19,21	25,26
St. 394 VII 21		
56°59′15″N		9°17′10″E
0	19,5	25,03
9,5	18,92	25,18
St. 396 VII 21		
57°01′10″N		9°27′50″E
0	20,5	24,56
6,5	19,91	24,65
St. 397 VII 21		
57°01′15″N		9°32′20″E
0	20,75	24,5
10	19,60	24,47
St. 398 VII 21		
57°01′45″N		9°36′45″E
0	21,8	24,4
8,5	20,12	24,4
St. 399 VII 21		
57°02′40″N		9°41′10″E
0	21,6	23,51
6,5	20,44	23,80
St. 400 VII 21		
57°03′40″N		9°45′15″E
0	21,7	23,64
6,5	20,50	23,66
12	20,42	23,69
St. 401 VII 21		
57°04′10″N		9°47′30″E
0	21,4	23,71
8	20,50	23,69
St. 403 VII 21		
57°02′50″N		9°51′E
0	21,3	23,46
10	20,9	23,60
14	20,6	23,59
St. 408 VII 22		
57°04′12″N		9°58′20″E
0	20,7	22,6
11,5	20,7	22,99
St. 409 VII 22		
57°05′N		10°01′30″E
0	20,6	22,23
11	20,6	22,66
St. 411 VII 22		
57°02′30″N		10°06′E
0	19,8	19,52
7,5		22,16
10,5	19,96	22,21

m	$t°C$	$S‰$
St. 413 VII 22		
56°59′35″N		10°11′10″E
0	19,6	18,73
5	20,5	21,49
10,5	19,1	22,32
St. 415 VII 22		
56°59′N		10°15′25″E
0	19,2	16,78
7,5	20,10	21,85
15	19,11	22,21
St. 419 VII 22		
56°58′15″N		10°24′E
0	18,8	15,84
5	15,11	24,05
7	13,72	24,85
St. 430 VII 30		
56 58′15″N		10°24′E
0	17,0	19,51
6	16,95	21,85
St. 434 VII 30		
56°59′N		10°15′25″E
0	19,4	20,79
7,5	18,71	22,30
15,5	18,61	22,52
St. 436 VII 30		
56°59′35″N		10°11′10″E
0	19,6	20,82
5	18,84	22,14
7,5	18,61	22,54
10,5	18,76	22,65
St. 438 VII 30		
57°02′30″N		10°06′E
0	20,0	19,61
9	18,56	23,22
St. 440 VII 30		
57°05′N		10°01′30″E
0	20,4	
2,5	18,68	21,78
7,5	18,41	23,22
12	18,41	23,28
St. 443 VII 31		
57°02′50″N		9°51′E
0	19,2	24,14
7,5	19,22	24,14
14,5	19,18	24,18
St. 445 VII 31		
57°04′10″N		9°47′30″E
0	19,0	24,18
8	18,90	24,18
St. 446 VII 31		
57°03′40″N		9°45′15″E
0	19,0	24,10
8	19,08	24,11
St. 447 VII 31		
57°02′40″N		9°41′10″E
0	19,1	24,04
7,5	19,0	24,27

m	$t°C$	$S‰$
St. 450 VII 31		
57°01′45″N		9°36′45″E
0	19,1	24,90
9	18,86	24,87
St. 451 VII 31		
57°01′15″N		9°32′20″E
0	19,0	24,78
9,5	18,85	24,79
St. 452 VII 31		
57°01′10″N		9°27′50″E
0	19,1	24,50
8,5	18,87	24,81
St. 455 VII 31		
56°59′15″N		9°17′10″E
0	19,7	23,98
9,5	19,59	24,14
St. 457 VII 31		
56°57′N		9°08′E
0	19,0	24,85
7	18,80	25,14
St. 459 VII 31		
56°55′N		9°03′E
0	19,0	25,16
5	18,94	25,21
8	18,71	25,62
St. 460 VII 31		
56°53′30″N		9°02′E
0	19,0	25,28
9	18,80	25,79
St. 461 VII 31		
56°53′30″N		8°59′30″E
0	18,9	25,79
8	18,78	25,84
St. 463 VII 31		
56°55′N		8°56′30″E
0	19,1	25,90
7	19,04	25,88
St. 464 VII 31		
56°58′20″N		8°59′E
0	19,0	25,60
8	18,86	25,55
St. 466 VII 31		
56°58′35″N		8°55′30″E
0	19,0	24,90
7,5	18,73	25,37
16,5	18,96	25,81
17	18,48	25,79
17	18,53	
St. 468 VII 31		
56°57′30″N		8°53′E
0	18,95	24,80
8	18,61	25,21
St. 469 VII 31		
56°57′15″N		8°49′15″E
0	18,9	24,61
2,5	18,84	24,60
7	18,79	24,61

2 (continued). Stations, where observations from different depths are carried out.

m	t°C	S‰
St. 470 VII 31		
56°56′N		8°47′E
0	18,9	24,5
10	18,60	25,07
St. 471 VII 31		
56°55′N		8°45′E
0	18,8	24,5
11	18,60	24,49
St. 472 VII 31		
56°56′20″N		8°43′E
0	18,8	24,47
5	18,76	
11	18,60	24,47
St. 473 VII 31		
56°55′N		8°41′E
0	18,8	24,4
11,5	18,21	24,52
St. 474 VII 31		
56°54′N		8°39′30″E
0	18,8	24,45
7,5	18,50	24,45
13	18,06	24,60
St. 475 VII 31		
56°53′10″N		8°38′E
0	19,2	24.2
5	18,56	
10	18,40	24,51
15,5	17,88	24,76
St. 476 VII 31		
56°51′20″N		8°38′15″E
0	19,0	24,11
7,5	18,71	24,11
14	17,87	24,69
St. 478 VII 31		
56°48′20″N		8°34′E
0	18,5	24,2
7,5	18,29	24,18
10	17,98	24,42
14	17,44	24,67
18	16,96	24,88
St. 479 VII 31		
56°46′N		8°31′20″E
0	18,6	24,20
6,5	18,00	24,29
St. 481b VIII 1		
56°43′10″N		8°30′18″E
0	18,0	23,75
6,5	18,00	24,20
St. 482 VIII 1		
56°41′45″N		8°33′20″E
0	18,35	24,24
8,5	18,56	24,47
St. 483 VIII 1		
56°44′35″N		8°36′E
0	18,55	24,4
3,5	18,72	25,01
St. 484 VIII 1		
56°40′30″N		8°37′E
0	18,8	24,87
2,5	18,90	25,77
4	18,81	28,66
St. 485 VIII 1		
56°40′N		8°38′40″E
0	18,95	25,2
4	18,88	28,68
6,5	18,86	28,78
St. 488 VIII 1		
56°38′40″N		8°39′40″E
0	18,7	26,82
5	18,80	28,93
St. 489 VIII 1		
56°37′10″N		8°40′E
0	18,6	27,18
2,5	18,86	28,82
4	18,98	28,82
7,5	18,91	28,95
14,5	18,91	29,11
St. 490 VIII 1		
56°36′N		8°37′E
0	19,1	29,08
5	18,86	29,56
St. 491 VIII 1		
56°34′40″N		8°33′45″E
0	19,0	29,3
20	18,71	29,72
St. 493 VIII 1		
56°34′30″N		8°29′E
0	19,1	29,6
5,5	18,57	30,2
St. 495 VII 1		
56°37′35″N		8°25′E
0	18,9	30,1
2,5	18,52	30,3
5,5	18,36	30,59
St. 496 VIII 1		
56°40′10″N		8°20′30″E
0	18,9	30,5
2,5	18,00	
5,5	17,82	30,52
St. 497 VIII 1		
56°41′N		8°19′E
0	18,7	30.6
5	18,12	30,70
St. 499 VIII 1		
56°39′35″N		8°14′30″E
0	18,5	30,7
3	18,09	30,66
St. 501 VIII 1		
56°42′25″N		8°14′E
0	18,2	30,3
6	17,97	30,30
St. 503 VIII 1		
56°37′35″N		8°19′40″E
0	18,8	30,7
5	18,70	30,84
St. 505 VIII 1		
56°35′30″N		8°23′15″E
0	18,4	30,6
5	18,20	30,82
St. 508 VIII 1		
56°34′30″N		8°36′E
0	19,6	29,3
4,5	19,01	29,6
St. 510 VIII 1		
56°31′10″N		8°37′20″E
0	19,3	29,0
5	18,94	
9,5	19,01	29,42
St. 511 VIII 1		
56°30′15″N		8°38′30″E
0	19,2	28,8
5	19,21	28,84
St. 513 VIII 1		
56°33′30″N		8°41′20″E
0	20,0	29,0
5,5	19,4	29,13
St. 514 VIII 1		
56°36′15″N		8°40′30″E
0	20,2	29,0
5	19,16	29,09
St. 517 VIII 1		
56°40′N		8°44′30″E
0	19,7	28,4
6	19,10	28,59
St. 519 VIII 1		
56°42′35″N		8°49′E
0	19,6	27,9
9,5	19,06	28,08
St. 521 VIII 1		
56°47′N		5°51′45″E
0	19,7	26,2
10	19,12	27,38
15	19,00	27,7
22	18,91	27,74
St. 523 VIII 2		
56°48′N		8°54′E
0	19,4	26,8
7,5	19,26	26,80
St. 524 VIII 2		
56°49′10″N		8°55′E
0	19,4	26,4
2,5	19,27	
7	19,29	26,44
St. 525 VIII 2		
56°50′15″N		8°52′E
0	19,5	26,4
6,5	19,35	26,42
St. 526 VIII 2		
56°50′40″N		8°56′E
0	19,2	26,3
7,5	19,20	26,40
St. 527 VIII 2		
56°51′30″N		9°00′E
0	19,2	25,9
7,5	19,20	25,88
St. 528 VIII 2		
56°51′20″N		9°04′E
0	19,05	25,9
5	18,99	
10,5	18,94	26,82
St. 529 VIII 2		
56°50′30″N		9°06′30″E
0	19,15	25,03
5	19,06	24,99
10,5	18,83	25,88
St. 530 VIII 2		
56°49′N		9°05′E
0	19,5	24,90
2,5	19,06	
7	18,90	25,37
St. 531 VIII 2		
56°48′N		9°01′30″E
0	19,3	25,97
5	19,01	26,80
8	18,94	
11,5	18,89	
14	18,90	27,29
St. 533 VIII 2		
56°48′15″N		9°08′50″E
0	19,1	24,27
9,5	18,70	25,73
St. 534 VIII 2		
56°45′30″N		9°09′50″E
0	18,9	24,81
5	18,74	
10,5	18,44	26,04
St. 536 VIII 2		
56°42′N		9°11′E
0	19,2	21,87
5	18,91	22,97
7,5	18,40	25,03
10	18,26	25,39
15	18,29	
20	17,26	25,62
St. 537 VIII 2		
56°39′25″N		9°11′E
0	19,4	21,13
5	19,26	22,07
7,5	18,00	24,67
St. 538 VIII 2		
56°39′N		9°15′30″E
0	18,8	20,81
5,5	18,29	22,77
St. 539 VIII 2		
56°36′20″N		9°17′30″E
0	18,2	22,27
2,5	17,99	22,72
5	17,68	24,05
7,5	17,50	24,43
10,5	17,29	24,81
St. 541 VIII 2		
56°38′40″N		9°07′E
0	19,4	22,05
2,5	19,33	22,09
6	17,89	24,90
St. 542 VIII 2		
56°36′25″N		9°04′20″E
0	19,3	22,11
4	19,24	22,12
St. 545 VIII 3		
56°50′30″N		9°09′40″E
0	18,7	24,51
5	18,67	24,51
10	18,51	25,23
St. 546 VIII 3		
56°52′15″N		9°09′40″E
0	18,6	24,34
2,5	18,53	24,36
7,5	18,51	24,38
St. 547 VIII 3		
56°54′30″N		9°08′E
0	18,7	24,72
7,5	18,64	24,76
St. 548 VIII 3		
56°56′15″N		9°05′45″E
0	18,8	24,20
7,5	18,68	24,72
St. 549 VIII 3		
56°57′N		9°08′30″E
0	18,7	24,42
6,5	18,70	24,63
St. 551 VIII 3		
57°01′10″N		9°27′50″E
0	18,8	24,13
8	18,60	24,07
St. 552 VIII 3		
57°01′45″N		9°36′45″E
0	19,0	24,61
2,5	18,92	24,60
6,5	18,91	24,60
St. 553 VIII 3		
57°02′40″N		9°41′10″E
0	19,8	24,61
6	18,76	
St. 554 VIII 3		
57°04′10″N		9°47′30″E
0	19,2	24,07
10	19,08	24,07

III.

Quantitative Investigations of Bottom Invertebrates in the Limfjord 1910—1927 with Special Reference to the Plaice-Food.

By

H. BLEGVAD

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1 chart, 2 diagrams, and 2 tables accompany the text.

Introduction.

The quantitative bottom investigations ("valuations") in the Limfjord, which for many years have been carried out annually by the Biological Station with the aid of Dr. Petersen's Bottom Sampler have been dealt with, as far as the years 1909—1917 are concerned, by Boysen Jensen (Rep. Danish Biol. Station 26, 1919); the quantity of fish food in the largest broads, Nissum, Thisted, and Livø Broads, has moreover been discussed by the present writer as regards the years up to and

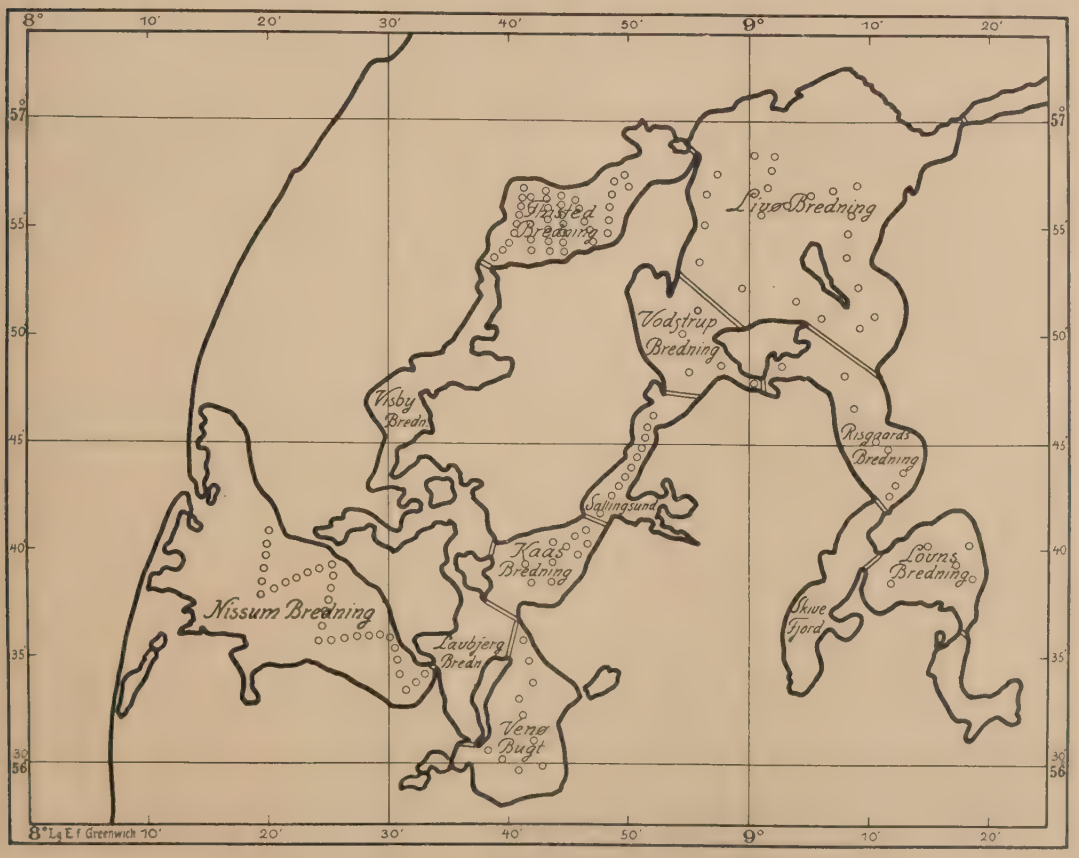

Chart of the Valuation Stations in the Limfjord 1918—27.

including 1924 (Rep. Danish Biol. Station 31, 1925 pp. 39—52). The former paper contains a chart showing the position of the stations; in 1918 and since then the position has been changed to some extent, wherefore a chart accompanies this paper to show the present position of the stations; some few stations to the west of Mors and in the smaller broads, Lavbjerg Broad and Skive Fjord are however not included partly because they are of little interest and partly because they are not repeated regularly every year. At each of the stations marked on the chart, a bottom sample has been taken twice (sometimes three times) a year with a 0,1 sq. metre bottom sampler. Only in 1927 were samples taken in the autumn alone, and only in the eastern and northern broads. The animals picked up in each broad were weighed immediately after capture, each species separately, so that it is now possible to trace the fluctuations in the amount by weight of bottom animals in the different broads year after year. That the samples are sufficiently representative to justify such a comparison is clear from the comparatively slight variations in the number of bottom animals caught at the different stations within each area (see for instance Tables I—IV in Rep. Dan. Biol. St. 20, 1911, in which the mean error is calculated).

Variations in the quantity of plaice-food 1918—1927.

I have previously emphasized the fact (Rep. Danish Biol. St. 31, 1925, pp. 29, 30) that amongst the bottom animals which serve as fish food, a distinction must be made between 1st class fish food, i. e. animals which wherever they occur are eagerly sought by the fish, and 2nd class fish food, i. e. animals which are only rarely eaten by the fish, and then as a rule only in localities where there is a lack of 1st class fish food.

As regards the Limfjord the following animals are 1st class plaice-food:

All *Polychæta*.

Lesser crustacean forms such as *Amphipods*, *Cumacea*, *Isopods*.

All *Lamellibranchs* with the exception of *Corbula gibba*, *Nucula nitida*, and the large thick-shelled forms, *Mytilus*, *Pecten*, *Tapes*, *Cyprina*, and *Mya*, when they are over 3 cm. in length. The young stages, particularly of *Cyprina* and *Mya truncata* are on the other hand 1st class plaice-food.

The *Gastropods Philine aperta* and *Acera bullata*.

2nd class plaice-food:

Corbula gibba, *Nucula nitida*.

In the following Table I I have calculated, on the basis of bottom sampler investigations, the quantity of 1st and 2nd class plaice-food expressed in grams per sq. metre of bottom in the different broads of the Limfjord. The most important species of food animals are given separately. As all the data with reference to the bottom sampler investigations in the Limfjord in the years 1909—1917 have been previously published in Dr. Boysen Jensen's above mentioned paper, I reproduce here only the figures for 1918—1927. Only for Vodstrup Broad, which is here for

the first time considered apart from Livø Broad, are the figures entered for as many years back as possible; the figures for the crustaceans are so low that for practical reasons they are everywhere omitted. In the last column, the average weight of the food animals for all the years of investigation is given for each area of water.

The great variations which are found throughout the entire Limfjord in the quantity of the animals on which plaice feed are due (see Boysen Jensen 1919, Blegvad 1925) to the following:

1) The same amount of fry does not develop each year. Fry is produced, so far as the great majority of food animals are concerned, in the summer half of the year; consequently autumn investigations reveal as a rule a greater quantity of food than do those in the spring. For the special conditions prevailing in Thisted Broad see Blegvad 1925, pp. 42, 43.

2) The most important of the animals on which plaice feed live for only one year or at the outside two years in the Limfjord. Thus *Abra alba* and *Abra nitida* are one-yearly species in the Limfjord, as also *Pectinaria koreni*, *Scalibregma inflatum*, *Acera bullata*, and *Philine aperta*. *Solen pellucidus* lives two years at the outside, as also *Cardium fasciatum* and probably *Nephthys hombergi*, *Nereis virens* and several other Polychæta; the main bulk of even the two-yearly species has usually disappeared after one year has elapsed. The animals which live for several years are either 2nd class fish food, such as *Corbula gibba* and *Nucula nitida*, or only serve as fish food in their first and second years, such as the 2 *Mya*-species. As I have previously emphasized (Blegvad 1925 pp. 46, 47) the rapid disappearance of the 1st class food animals can only in Nissum Broad be looked upon as due to the attacks of their enemies, which are first and foremost the fish. Plaice namely are so dense there that the species of animals which constitute their favourite food are steadily kept down to a minimum both with respect to age and size[1]); plaice are therefore compelled to a great extent to subsist on 2nd class food, viz., *Corbula gibba* and *Nucula nitida*. In the inner Limfjord on the other hand we must assume that food animals are usually present in such numbers that the amount consumed by plaice cannot play any great part. Other factors, in particular probably the low temperature in the winter and the covering of the sea bottom with mud or dead seaweed, must here be the most important; it is namely particularly in winter time that the bottom invertebrates perish en masse.

[1]) See "Naturen", Bergen, for January 1927, pp. 22—29, in which is described an attempt by me to determine the amount of food consumed by the fish in Nissum Broad by setting out boxes of wood and wire-gauze in the broad and letting them stand there throughout one summer. It was found that of the 1st class food animals such as *Abra*, *Tapes*, *Cardium*, and *Pectinaria* there was an upgrowth of up to 60 times as many specimens per sq. metre of bottom as on the bottom of the broad outside the boxes; of the 2nd class fish food on the other hand, there were about the same number per sq. metre within the boxes as outside them. According to the figures obtained from this experiment the number of food animals consumed by the fish in Nissum Broad in the course of four summer months was about 400—600 *Abra*, about 100 *Pectinaria* and about 100 small molluscs of different kinds, all per sq. metre of bottom. This experiment was carried out in 1925. A fresh experiment in 1926 which was undertaken both in Nissum and Thisted Broad was unfortunately unsuccessful owing to the marking-buoys drifting away in a storm.

Table 1. Quantity of 1st and 2nd class plaice-food in the different broa

Thisted Broad. 1st cla

	Year	1918		1919		1920		1921		
	Date	29/5	5/9	13/5	28/9	15/5	16/9	26/4	2/8	23/9
1st cl. food animals	Abra alba	55,13	3,25	0	2,20	4,50	1,95	0,03	13,20	16,2
	Solen pellucidus	45,28	23,75	8,03	4,55	6,15	2,75	1,88	6,93	36,6
	Other Molluscs	15,72	11,48	3,39	9,19	7,83	6,26	7,42	6,94	10,4
	Pectinaria koreni	11,55	3,80	1,50	2,50	0,78	0,25	0,38	4,55	8,7
	Polychæta	8,89	5,51	5,70	3,43	4,39	4,22	3,97	6,17	6,6
	Total	136,57	47,79	18,62	21,87	23,65	15,43	13,68	37,79	78,7

Livø Broad. Food animal

	Year	1918		1919		1920		1921		
	Date	1/6	5/9	8/5	29/9	15/5	15/9	21/4	29/7	27/9
1st cl. food animals	Abra alba + nitida	3,04	5,35	0,12	3,68	0,72	0,40	0	2,80	3,4
	Solen pellucidus	17,52	17,50	3,80	10,64	2,20	1,56	0,80	1,52	13,5
	Other Molluscs	5,04	3,58	2,04	8,68	1,56	6,96	1,40	10,96	16,8
	Pectinaria koreni	7,68	1,50	0,52	2,36	0,12	4,28	0,08	8,28	7,3
	Polychæta	5,08	3,65	2,96	4,36	8,64	5,56	4,32	9,36	5,8
	Total	38,36	31,58	9,44	29,72	13,24	18,76	6,60	32,92	47,0
2nd cl. food animals	Nucula nitida	4,00	9,00	5,92	5,20	3,08	5,44	4,00	3,68	6,9
	Corbula gibba	34,16	47,57	11,60	3,28	2,24	2,60	2,28	13,12	28,9
	Total	38,16	56,57	17,52	8,48	5,32	8,04	6,28	16,80	35,8

Fur-Sound—Risgaards Broa

	Year	1918	1919		1920		1921		
	Date	4/9	5/5	3/10	8/5	20/9	27/4	1/8	24/9
1st cl. food animals	Abra alba + nitida	1,10	0,30	12,40	4,20	0	0	9,30	8,80
	Solen pellucidus	2,50	3,00	1,70	2,30	0,80	1,60	4,20	18,20
	Other Molluscs	10,60	*23,50	8,50	*56,70	0,80	0,60	4,10	2,30
	Pectinaria koreni	4,70	1,80	3,90	4,50	0	0,80	7,80	2,70
	Polychæta	3,00	2,60	3,70	2,50	3,60	3,00	4,00	4,80
	Total	21,90	31,20	30,20	70,20	5,20	6,00	29,40	36,80
2nd cl. food animals	Nucula nitida	4,40	1,20	3,40	1,20	1,60	2,60	1,30	2,70
	Corbula gibba	4,20	2,30	1,70	1,30	0,10	1,20	3,60	2,70
	Total	8,60	3,50	5,10	2,50	1,70	3,80	4,90	5,40

*) 20,0 g. Mya juv.

*) 47,0 g. Mya juv.

the Limfjord in grams (rough weight) per sq. metre of bottom.

d animals. Rough weight in g. per sq. m.

1922		1923		1924		1925		1926			1927	Average for 18 years
17/6	10/9	10/5	13/9	25/5	8/9	20/5	14/9	21/4	21/7	26/9	20/9	
3,75	16,65	18,45	6,13	0,36	5,08	5,63	0,58	0	0,40	0,65	18,08	9,46
3,35	24,56	5,15	2,38	5,85	7,25	1,30	2,13	1,95	0,50	1,15	2,06	10,12
3,66	11,63	5,23	9,67	9,40	3,32	1,59	4,04	4,86	5,10	3,80	2,29	13,18
2,13	1,45	0,88	0,25	0,55	0,05	0,40	0,40	0,20	0,30	1,00	0,35	4,04
2,88	10,27	15,47	8,75	8,83	11,60	9,02	8,07	5,27	6,30	4,85	2,95	5,86
2,77	64,56	45,18	27,18	24,99	27,30	17,94	15,22	12,28	12,60	11,45	25,73	42,66

ough weight in g. per sq. m.

1922		1923		1924			1925		1926			1927	Average for 15 years
22/6	11/9	4/5	13/9	26/5	8/7	7-8/9	20/5	17/9	19/4	20/7	26/9	19/9	
3,72	29,84	2,44	58,80	1,80	13,00	11,20	0,08	4,48	0,08	1,48	0,60	1,04	6,53
1,20	6,92	1,88	2,32	0,20	0,40	3,48	1,32	2,24	0,04	0,20	1,12	0,40	7,37
1,56	4,72	2,28	6,20	6,80	3,30	9,04	4,40	7,12	2,64	0,80	11,08	2,76	4,73
0,20	5,56	0,04	1,64	0,24	0	3,16	0,08	3,96	0,48	0,32	1,00	0,40	5,62
0,64	8,32	5,84	11,60	13,88	8,60	9,52	8,04	11,68	8,68	6,48	3,80	1,44	6,61
7,32	55,36	12,48	80,56	22,92	25,30	36,40	13,92	29,48	11,92	9,28	17,60	6,04	30,86
7,44	6,40	6,52	9,32	2,36	1,40	7,12	4,68	6,16	5,88	5,92	4,80	3,32	5,59
1,20	25,80	14,44	41,80	3,80	4,60	10,16	5,20	41,92	5,80	25,68	24,28	44,08	17,94
8,64	32,20	20,96	51,12	6,16	6,00	17,28	9,88	48,08	11,68	31,60	29,08	47,40	23,53

ood animals. Rough weight in g. per sq. m.

1922		1923	1924		1925		1926			1927	Average for 13 years
23/6	14/9	11/9	24/5	13/9	19/5	16/9	18/4	19/7	27/9	18/9	
23,20	12,70	6,10	2,20	1,70	0	5,20	0	0,60	0,10	0,70	4,94
12,40	6,20	0,10	0,40	0,60	1,00	1,40	0,20	0	0	0,40	3,33
0,70	5,00	8,30	4,60	3,80	1,60	6,50	5,20	4,60	1,00	1,10	8,22
0,40	0	0,80	1,70	0,30	0,50	1,70	0,80	0,40	0	0,20	1,58
5,80	4,90	3,60	2,70	15,30	11,70	13,20	21,50	7,60	6,40	1,50	5,93
42,50	28,80	18,90	11,60	21,70	14,80	28,00	27,70	13,20	7,50	3,90	24,00
3,10	4,80	1,50	0,70	1,20	0,50	1,90	0,20	0	0,50	0	2,02
1,00	0,20	2,20	3,50	5,00	3,20	6,80	1,40	11,00	8,50	3,00	8,17
4,10	5,00	3,70	4,20	6,20	3,70	8,70	1,60	11,00	9,00	3,00	10,19

Lovns Broad. Food animal

	Year	1918	1919		1920		1921	
	Date	4/9	5/5	3/10	8/5	20/9	1/8	24/9
1st cl. food animals	Abra alba + nitida	0,60	0	26,00	18,00	0	1,00	0,80
	Mya truncata juv.	2,00	0	0	0	0	0	0
	Other Molluscs	*29,60	*18,40	1,40	1,60	1,60	8,60	*33,20
	Pectinaria koreni	0	0,40	0,60	0	0	1,20	2,00
	Polychæta	4,00	0,80	1,80	5,00	2,60	4,80	2,60
	Total	36,20	19,60	29,80	24,60	4,20	15,60	38,60
2nd cl. food animals	Corbula gibba	0,80	0,80	0,40	0	0	0,20	0
		*) 18,2 g. Acera	*) 17,0 g. Acera					*) 21,6 g. Solen

Vodstrup Broad. Food animals

	Year	1915	1916			1917		1918		1919		1920	
	Date	12/8	8/5	25/7	16/9	22/5	6-7/10	29/5	5/8	8/5	3/10	15/5	20/9
1st cl. food animals	Abra alba + nitida	1,70	1,00	21,00	12,60	0	11,0	4,7	1,60	0,50	3,60	0,60	0
	Solen pellucidus	0,80	0,60	0,80	2,60	0	87,7	34,2	21,60	2,40	3,20	0,80	0,20
	Other Molluscs	0,10	1,00	0,40	0,10	1,00	0,3	2,3	4,00	2,00	19,00	0,20	3,20
	Pectinaria koreni	3,20	0,20	0,20	0,60	0	17,6	4,0	0	3,00	1,40	0,40	0,30
	Polychæta	1,60	1,80	3,80	3,60	1,20	4.0	8,0	4.80	3,60	3,20	8,80	1,60
	Total	7,40	4,60	26,20	19,50	2,20	120,6	53,2	32,00	11,50	30,40	10,80	5,30
2nd cl. food animals	Nucula nitida	3,50	1,20	2,00	3,40	1,20	2,6	5,4	6,80	4,60	7,20	2,20	4,00
	Corbula gibba	53,90	23,60	27,00	39,40	14,40	9,9	84,2	76,00	40,40	8,20	6,60	2,40
	Total	57,40	24,80	29,00	42,80	15,60	12,5	89,6	84,60	45,00	15,40	8,80	6,40

Sallingsund. Food animals.

	Year	1918		1919		1920		1921		
	Date	28/5	2/9	3/5	30/9	12/5	18/9	23/4	30/7	25/9
1st cl. food animals	Abra alba + nitida	28,60	5,90	0,20	9,90	4,20	0,10	0,10	12,10	13,90
	Solen pellucidus	264,20	270,00	26,70	12,40	1,30	0,30	0,70	6,70	33,70
	Other Molluscs	5,60	5,70	6,70	*32,70	5,80	1,40	0,10	0,90	1,10
	Pectinaria koreni	27,60	6,50	13,00	8,20	0,40	0,50	1,20	10,80	11,20
	Polychæta	10,80	6,90	4,90	7,40	8,70	4,40	5,40	7,70	12,70
	Total	336,80	295,00	51,50	70,60	20,40	6,70	7,50	38,20	72,60
2nd cl. food animals	Nucula nitida	13,00	16,60	13,00	19,20	9,70	14,20	20,20	16,60	17,10
	Corbula gibba	150,60	270,00	207,00	271,20	176,60	272,20	180,30	263,90	233,00
	Total	163,60	286,60	220,00	290,40	186,30	286,40	200,50	280,50	250,10
					*) 28,0g. Mya tr. juv.					

ugh weight in g. per sq. m.

1922		1923	1924		1925		1926			1927	Average for 13 years
$^{12}/_{6}$	$^{14}/_{9}$	$^{11}/_{9}$	$^{24}/_{5}$	$^{13}/_{9}$	$^{19}/_{5}$	$^{16}/_{9}$	$^{18}/_{4}$	$^{20}/_{7}$	$^{27}/_{9}$	$^{18}/_{9}$	
,80	0,40	171,20	0,80	0	0	60,00	0	0,40	2,20	2,40	17,86
)	0	103,00	129,00	80,00	57,40	0	0	0	0	0	19,82
,80	0	1,00	0,60	8,00	*87,00	*55,60	2,60	5,20	*24,20	5,40	4,83
)	0	0,80	5,00	1,20	0,60	0	0	0	0	0	1,51
,80	1,80	3,60	2,80	4,80	12,80	11,20	13,00	11,60	6,00	2,00	4,88
1,40	2,20	279,60	138,20	94,00	157,80	126,80	15,60	17,20	32,40	9,80	48,90
)	0	2,40	2,60	3,00	0,40	0	1,20	0	0,20	0,80	2,48
					*) 63,4 g. Mya arenaria 20 g. Mac. baltica	*) 49,2 g. Macoma baltica			*) 16 g. Mac. baltica 8 g. Acera		

ugh weight in g. per sq. m.

	1921		1922		1923	1924		1925		1926			1927	Average for 13 years
$^{7}{}_{4}$	$^{1}/_{8}$	$^{27}/_{9}$	$^{23}/_{6}$	$^{14}/_{9}$	$^{12}/_{9}$	$^{26}/_{5}$	$^{13}/_{9}$	$^{20}/_{5}$	$^{17}/_{9}$	$^{19}/_{4}$	$^{20}/_{7}$	$^{27}/_{9}$	$^{19}/_{9}$	
)	1,70	2.80	0,60	1,60	35,60	1,60	3,20	0	4,80	0	3,00	0	6,20	4,59
,00	4,40	20,80	1,60	2,10	15,80	0	3,00	1,10	0	0	0	0,40	0,20	7,90
,30	16,80	20,60	1,20	0,80	1,10	0,80	5,90	2,00	22,90	2,80	3,20	1,60	1,40	4,42
,60	5,60	2,20	0	0,20	1,80	0,80	0,20	0	0	0	0,80	0	0,40	1,71
1,40	3,80	2,40	6,40	4,30	8,00	6,40	7,80	2,00	12,90	5,40	8,60	2,60	2,20	4,62
4,30	32,30	48,80	9,80	9,00	62,30	9,60	20,10	5,10	40,60	8,20	15,60	4,60	10,40	23,24
3,60	2,60	4,40	1,40	2,20	7,50	1,00	1,20	0,70	4,20	2,00	1,20	0,60	3,00	3,13
,00	25,00	10,40	13,80	14,40	19,40	3,00	14,40	8,80	148,00	17,00	101,80	103,80	198,40	41,27
2,60	27,60	14,80	15,20	16,60	26,90	4,00	15,60	9,50	152,20	19,00	103,00	104,40	201,40	44,40

ough weight in g. per sq. m.

1922		1923		1924		1925		1926			Average for 12 years
$^{21}{}_{6}$	$^{13}/_{9}$	$^{5}/_{5}$	$^{11}/_{9}$	$^{21}/_{5}$	$^{12}/_{9}$	$^{18}/_{5}$	$^{15}/_{9}$	$^{16}/_{4}$	$^{19}/_{7}$	$^{23}/_{9}$	
13.50	7,10	8,80	44,60	4,10	14,60	3,60	0,30	0	1,00	0,80	8,15
45,40	10,80	4,00	12,20	0,80	0,90	0,80	0	0,20	0	0	33,44
0,40	1,60	1,50	6,70	0,20	0,90	0,70	0,50	0,20	3,40	1,00	3,18
8,60	11,50	0,90	1,90	1,30	5,10	0	0,40	0,20	0,80	1,40	6,42
8,00	6,30	5,80	*25,50	12,60	*20,60	5,30	*23,30	*44,80	*20,40	*25,10	10,97
75.90	37.30	21.00	90,90	19,00	12,10	10,40	24,40	45,40	25.60	28.30	62.16
13.00	19,80	12,80	19,40	1,60	3,10	7,70	14,60	13,50	12,00	14,40	13,20
42.10	203,50	127,00	112,00	1,80	5,00	7,00	551,00	337,50	376,40	430,00	223,25
55.10	223,30	139,80	131,40	3,40	8,10	14,70	565,60	351,00	388,40	444,40	236,45
			*) 18,6 g. Nereis		*) 9,8 g. Nereis		*) 8,1 g. Nereis	*) 39,7 g. Nereis	*) 5,8 g. Nereis 9,4 g. Scalibregma	*) 7,0 g. Nereis	

Kaas Broad. Food animals

	Year	1918		1919		1920		1921		
	Date	5/6	3/9	3/5	2/10	12/5	18/9	23/4	3/8	25/9
1st cl. food animals	Abra alba + nitida	8,70	3,88	0	0,80	0,30	0	0	2,10	1,40
	Solen pellucidus	60,00	1,25	2,00	4,60	0,20	1,10	0,50	6,10	1,50
	Other Molluscs	3,70	1,75	1,30	5,60	0,90	2,50	0,70	4,30	7,30
	Pectinaria koreni	4,60	1,13	0,	1,50	0	1,60	0,20	6,20	0.50
	Polychæta	13,80	5,88	2,90	2,90	2,80	4,00	*14,30	5,00	4,40
	Total	90,80	13,89	6,20	15,40	4,20	9,20	15,70	23,70	15.10
2nd cl. food animals	Nucula nitida	7,60	8,38	6,30	10,50	1,60	4,80	5,20	3,50	4,90
	Corbula gibba	215,90	107,25	38,40	38,50	56,00	82,50	81,80	134,50	98,30
	Total	223,50	115,63	44,70	49,00	57,60	87,30	87,00	138,00	103,20

*) 12,1 g. Nereis virens

Venø Bay. Food animals

	Year	1918		1919		1920		1921		
	Date	5/6	3/9	15/5	2/10	12/5	18/9	23/4	3/8	25/9
1st cl. food animals	Abra alba + nitida	0,10	2,80	3,20	16,80	14,80	0,20	0,20	1,40	1,20
	Solen pellucidus	0,20	3,20	1,50	27,70	5,60	0,60	0	5,10	23,80
	Other Molluscs	2,40	5,90	0,90	12,90	2,40	5,50	1,40	5,40	11,30
	Pectinaria koreni	0,20	0,60	0	10,80	1,00	0,80	0	3,50	4,50
	Polychæta	2,40	2,60	2,40	8,00	5,50	4,00	2,30	3,00	*32,70
	Total	5,30	15,10	8,00	76,20	29,30	11,10	3,90	18,40	73,50
2nd cl. food animals	Nucula nitida	2,40	2,20	0,90	6,40	0,80	0,30	0,60	1,30	0,50
	Corbula gibba	19,50	5,00	25,50	10,20	8,80	1,20	1,70	19,00	0,90
	Total	21,90	7,20	26,40	16,80	9,60	1,50	2,30	20,30	1,40

*) 29,2 g. Nereis

Nissum Broad East.

	Year	1918		1919		1920		1921		
	Date	4/6	9/9	14/5	1/10	11/5	17/9	25/4	4/8	26/9
1st cl. food animals	Abra alba	1,60	1,90	2,57	0,70	1,10	0,67	0,07	7,07	1,20
	Other Molluscs	1,80	1,90	1,02	0,82	1,13	0,63	0,30	1,13	1,76
	Pectinaria koreni	0,50	0,90	0,10	1,97	0,17	1,00	0,47	4,47	1,90
	Polychæta	10,60	2,70	1,67	1,62	4,56	2,97	1,83	4,80	3,63
	Total	14,50	7,40	5,36	5,11	6,96	5,27	2,67	17,47	8.49
2nd cl. food animals	Nucula nitida	19,50	28,30	21,07	22,93	24,67	19,33	22,57	16,67	18,50
	Corbula gibba	40,80	40,80	30,40	83,67	137,33	256,67	233,33	360,00	353,33
	Total	60,30	69,10	51,47	106,60	162,00	276,00	255,90	376,67	371,83

ough weight in g. per sq. m.

1922		1923		1924		1925		1926			Average for 9 years
21/6	13/9	5/5	14/9	20/5	12/9	21/5	15/9	16/4	19/7	23/9	
4,80	9,50	1,30	60,80	0	0,90	0,50	0,80	0	2,40	1,10	5,16
0,40	4,30	0,50	5,80	0,20	0,10	0	1,80	0	0	0,30	10,28
0,50	8,90	1,50	2,90	0,90	1,10	0,40	4,90	1,20	0,80	2,80	2,70
0	3,00	0	0,70	0	0,40	0,10	0,40	0	0,20	0,30	1,04
7,00	4,70	5,30	*15,20	6,70	8,80	*21,10	*43,80	*16,00	6,40	10,20	10,08
12,70	30,40	8,60	85,40	7,80	11,30	22,10	51,70	17,20	9,80	14,70	9,26
3,60	4,30	3,50	5,30	2,00	5,10	7,00	9,20	5,50	8,40	7,00	5,81
74,10	96,50	56,40	83,90	10,40	7,20	3,90	157,80	76,00	286,00	404,00	105,10
77,70	100,80	59,90	89,20	12,40	12,30	10,90	167,00	81,50	294,40	411,00	110,91

*) 7,7 g. Nereis virens

*) 9,0 g. Nereis virens

*) 17,0 g. Nereis virens 26,3 g. Nephthys hombergi

*) 11,5 g. Nephthys hombergi

ough weight in g. per sq. m.

1922		1923		1924		1925		1926			Average for 11 years
30/6	13/9	5/5	15/9	20/5	12/9	23/5	13/9	17/4	17/7	24/9	
6,10	22,50	4,30	108,70	13,20	8,10	0,60	2,10	0,10	1,80	0,90	9,80
0,60	6,30	0,30	3,60	0,70	1,60	0,40	1,60	0,10	1,20	2,00	3,80
1,30	7,60	1,90	5,00	2,80	2,40	0,60	18,10	4,70	6,20	8,90	4,76
0	4,40	0	0,80	0,10	1,40	0	0,20	0	0	0,20	1,39
5,90	4,70	6,40	9,70	12,10	11,50	7,80	3,30	6,60	2,40	2,80	6,29
13,90	45,50	12,90	127,80	28,90	25,00	9,40	25,30	11,50	11,60	14,80	26,04
1,70	1,20	1,30	3,50	1,30	4,30	1,40	0,10	3,00	0	2,60	1,83
4,00	3,10	2,10	6,50	2,50	3,20	8,80	40,70	12,70	79,60	26,50	15,50
5,70	4,30	3,40	10,00	3,80	7,50	10,20	40,80	15,70	79,60	29,10	17,33

ood animals. Rough weight in g. per sq. m.

1922		1923		1924		1925		1926			Average for 17 years
19/6	12/9	7/5	14/9	19/5	9/9	22/5	11-12/9	22/4	17/7	25/9	
1,80	3,00	0,53	16,20	0,30	8,83	1,10	5,47	0	6,00	6,47	2,53
0,66	0,73	1,60	1,60	1,07	4,27	1,30	3,60	2,90	2,50	4,07	2,26
0	1,73	0,27	0,63	0	4,60	0,10	2,07	0,13	0,80	0,47	2,73
2,83	2,81	3,14	5,43	5,57	9,62	12,37	7,11	12,51	10,00	4,20	5,08
5,29	8,27	5,54	23,86	6,94	27,32	14,87	18,25	15,54	19,30	15,21	12,60
15,20	13,57	14,43	13,93	13,60	16,17	24,87	38,77	36,50	47,60	53,67	22,93
286,67	320,00	200,00	272,77	121,93	125,70	92,67	239,16	142,78	260,80	220,33	128,76
301,87	333,57	214,43	286,70	135,53	141,87	117,54	277,93	179,28	308,40	274,00	151,69

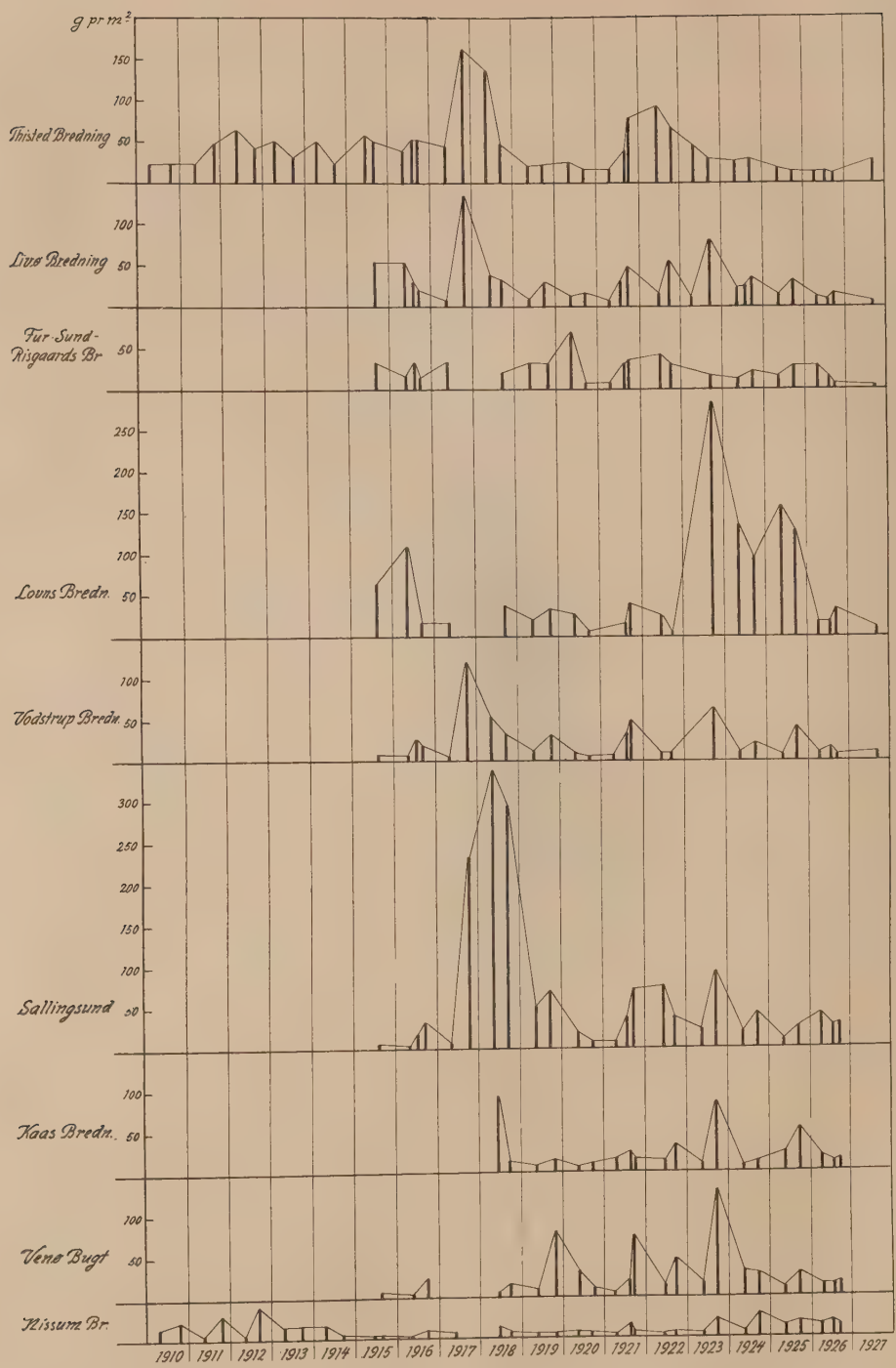

Fig. 1

Quantity of 1st class plaice-food in the different broads of the Limfjord 1910—1927 expressed in grams (rough weight) per sq. metre.

Since it is the variations in the quantity of 1st class plaice-food which above all else is of importance to the fishery, I have given in Fig. 1 a graphical presentment of them in the various areas of the Limfjord. The abscissae represent the times of the catches and the ordinates the amounts by weight (in grams per sq. metre of bottom). For the sake of comparison, the results of valuations in the years prior to 1918 are also given; but as Boysen Jensen (ibid. 1919) has dealt with these in detail, I shall below only concern myself with the years from and including 1918.

It will be noticed that 1918 in nearly all the broads gave a high figure in the spring, but decreasing amounts in the autumn. This is due to the fact that in 1917 throughout nearly the entire Limfjord unusually large quantities of fry of certain food animals developed, especially of *Solen pellucidus*, but in many places also of *Pectinaria koreni* and *Abra alba*. Of this fry from 1917 there was still in the spring of 1918 a certain amount left, but as only a comparatively slight upgrowth of the year's fry occurred in 1918, the amount of fish food available decreased considerably throughout the entire Limfjord. We express this by saying that 1917 was a good fry year (in this case especially for *Solen pellucidus*), whereas 1918 was a bad fry year. Neither were the years 1919 and 1920 good fry years for the animals on which plaice feed[1]); only in Venø Bay and Livø Broad did a little *Abra* and *Solen* fry develop in 1919, and in Sallingsund some *Mya* fry; in the spring of 1920 a number of young *Mya* were found in Risgaards Broad, but the autumn valuations of 1920 showed that the fry of the animals on which plaice feed was a failure throughout the entire Limfjord in this year. 1921 on the other hand was an unusually abundant fry year as regards *Solen*, *Abra*, and *Pectinaria*; the weight per sq. metre of the animals on which plaice feed was far greater than normal in almost every part of the Limfjord. In 1922 there was still some fry left from 1921 in many places, but only in Livø Broad did fresh fry of any importance appear. 1923 on the other hand was an excellent fry year, particularly for *Abra alba*, but in many places also for *Solen pellucidus*; in Lovns Broad there were found in addition to *Abra* great quantities of young *Mya*. Only in Thisted and Risgaards Broads was the quantity of plaice-food under the normal. In 1924 the year's fry appeared in comparatively small numbers in nearly all parts; only in Nissum Broad was there a certain amount of *Abra* and *Solen*. 1925 was a still worse fry year as regards the food animals of the plaice in Thisted and Livø Broads, Sallingsund, Venø Bay, and Nissum Broad; only in Lovns Broad was there a certain amount of *Abra* and *Mya* whilst in Kaas Broad there were unusually many polychæta, especially *Nephthys hombergi* and *Nereis virens*. 1926 was also an unusually bad fry year; the quantity of food animals was in all parts far below the normal; in Nissum Broad alone was the quantity slightly above normal, by reason of the production of a certain amount of young *Abra* and *Solen*. 1927 gave a still worse result in all the broads investigated, with the exception of Thisted

[1]) When here and in the following food animals are mentioned without any further designation, 1st class food animals are meant in every case.

Broad, where some *Abra* made an appearance; notwithstanding this, the total quantity was also there far below the average for all the years during which investigations have taken place.

Causes of the decrease in the quantity of plaice-food during the years 1924—1927.

By comparing the different curves in Fig. 1, it is at once obvious that both the quantity of 1st class fish food and the variations in this quantity are extremely small in Nissum Broad as compared with the other broads. It has been emphasized on page 37 that the reason for this is the overpopulation of plaice in this part of the Limfjord.

If we leave Nissum Broad, where special conditions thus prevail, out of account, it will appear from the foregoing that since 1918 great fluctuations have occurred in the quantity of food animals, but that since 1923 there has been no eminently good fry year throughout the whole of the inner Limfjord. Of the causes which may be regarded as contributory to the unusually small quantity of fry produced in this series of years, the following may be particularly emphasized:

1) Physical factors such as violent changes in the temperature, adverse changes in bottom conditions, etc. may have killed the tiny fry of the bottom invertebrates either in the pelagic stage or shortly after they have reached the bottom stage. We have at present however little knowledge of such conditions which as mentioned above undoubtedly also play a great part in the winter time. Boysen Jensen (1919, pp. 40, 41) did not succeed in demonstrating any connection between the occurrence of fry years and cold and warm summers.

2) As the number of spawning, adult animals gradually declines year by year, the quantity of eggs and pelagic larvae produced annually will also decline; one might imagine that this would also result in a decreased upgrowth of fry on the bottom. Yet there is no reason to believe that this is of any great importance to the animals under discussion. It has namely been observed that very abundant fry years often occur just when the adult stock has been down at an absolute minimum; thus for *Abra* and *Solen* in Thisted Broad in 1917 and 1921, and in Livø Broad in 1917, 1921, and 1923. On the other hand a bad fry year often occurs at a time when there is a particularly large stock of adult bottom animals present in the waters, as for instance in the case of *Abra*, *Pectinaria*, and *Solen* in Thisted Broad in 1918.

3) The amount of food animals may have been kept down during these years by fish and other predaceous animals even though an abundant quantity of fry has been forthcoming each year. As mentioned previously however, it is only in Nissum Broad that an effect of this kind can be shown to have been caused by the plaice; in the other broads this may be regarded as being of no great importance. It is therefore as a rule difficult to discover any correlation between the amount of fish food and the fishery statistics. Both Boysen Jensen (1919, pp. 20—22) and I myself (1925, pp. 49—52) have attempted to discover a correlation between the yield of

the plaice fishery and the amount of food, but usually without success. It must also be remembered that the amount of food present at a given moment only represents the surviving members of a stock of whose original numerical strength we are ignorant, and has therefore nothing to do with the production of fish food in the waters in question. One would really be most inclined to expect a correlation between the amount of food consumed by the fish and the production of fish in the waters in question; but here again we are ignorant as to how much of the food has been consumed by the predaceous animals amongst the larger bottom animals, e. g. large Gastropods, *Asterias*, Ophiurae, *Nereis*, *Nephthys* etc. Boysen Jensen (1919, pp. 8—15 and Table II) on the basis of the spring valuations has attempted to calculate the annual production and consumption in Thisted Broad for the years 1910—1915; but his figures are, as he himself observes (p. 8), owing to the nature of the case not very accurate; they are also doubtless too low for the reasons mentioned above. Only experiments, of the kind mentioned in the footnote on page 37, where the bottom animals grow up naturally in boxes can give us any information as to the food consumed by the fish, and thereby possibly as to the annual production. The number of plaice in the broads of the inner Limfjord have been declining in recent years, so for that reason alone the amount of food consumed by the plaice cannot be the cause of the decrease in the quantity of food animals. Nor, so far as is known, have any predaceous animals amongst the bottom invertebrates increased in quantity to such a degree that they can be suspected of being the cause.

There is, however, a fish which in recent years has spread to a surprising extent all over the Limfjord; this is the viviparous blenny (*Zoarces viviparus*). This fish feeds in the Limfjord on just the same animals as does the plaice (see H. Blegvad: On the Food of Fish, etc. in Rep. Danish Biol. St. 24, 1916, p. 53 and List 2), and there is therefore reason to believe that an occurrence en masse of Zoarces may be a contributory cause of the quantity of food animals among the bottom invertebrates being kept down at a minimum. Whereas the Zoarces in former years practically kept to the Zostera region or in the immediate neighbourhood of it, they have since 1923 spread over the soft bottom of the large broads in steadily increasing numbers. To give some idea of the number of Zoarces involved it may be mentioned that quite a little fleet of fishing boats fished for Zoarces fry to be used as bait for eel hooks, every day throughout the entire Limfjord in recent summers; a fisherman in Nykøbing Mors reported that about 1000 Zoarces fry (mostly of the 0- and I-groups) were caught per haul, or about 10.000 per boat per day. The former director of the Danish Biological Station, Dr. C. G. Joh. Petersen, called attention in a short paragraph in the "Berlingske Tidende" in July 1926 to the occurrence en masse of Zoarces in the Limfjord; he at the same time laid stress on the fact that there was presumably a connection between this and the great decrease in recent years in the number of cod.

The Zoarces is as is well known one of the food animals most prized by the

Table 2. Variations in the occurrence of cod, Zoarces viviparus, and Gobius niger in the Limfjord, Districts A + B (W. of Løgstør).

Year	Number of Zoarces caught per 10 minutes' trawling with Eel-tog. Number of hauls in brackets	Yield of the cod fishery in 1000 kg.	Caught with Eel-tog:	
			Age and quantity of cod	Gobius niger
1908	0,9 (26)	405,0	0-gr. predominant. A few I-, II-, and III-gr. Large numbers of cod everywhere	None
1909	4,7 (59)	415,7	I-gr. predominant. A few older; in Hvalpsund and Nissum Br. a few 0-gr. Cod in large numbers everywhere	Do.
1910	3,0 (87)	501,4	II-gr. predominant. A few 0- and I-gr. Numbers decreasing	Do.
1911	0,1 (26)	564,8	III-gr. predominant. A few I- and II-gr. Numbers decreasing	Do.
1912	0 (8)	594,4	IV-gr. predominant. A few V-gr. In Nissum Br. a few of 0-gr. Numbers decreasing	A few in Nissum Br.
1913	1,2 (16)	176,7	Only a few large cod, age not determined	Do. also in Thisted and Sallingsund
1914	0,3 (4)	83,6	No cod caught	A few
1915	3,8 (5)	73,3	Do., only in Nissum Br. 2 small cod	Some
1916	8,4 (13)	38,7	0-gr. only. Many cod everywhere	Many everywhere
1917	20,5 (10)	133,6	I-gr. only. Many cod everywhere	Do.
1918	15,5 (42)	267,5	Mostly II-gr. A few of 0-gr. especially in the west. Many cod everywhere	A few everywhere
1919	3,4 (24)	1052,7	Mostly III-gr. and I-gr. Many cod everywhere	None
1920	1,9 (35)	728,9	Mostly 0-gr., and then I- and II-gr. Numbers decreasing	Do.
1921	2,2 (54)	702,6	Mostly I-gr. A few III-gr. Numbers decreasing	Do.
1922	3,2 (33)	775,8	Only quite a few cod caught in Thisted and Nissum Broads	Do.
1923	5,9 (48)	219,8	No cod caught	Do.
1924	12,7 (31)	84,5	Do.	Do.
1925	19,8 (43)	78,0	Do.	A few in the autumn
1926	20,7 (72)	30,1	Cod especially sought for, but only 4 specimens caught altogether in 72 hauls (Risgaard Br.: 3 of 0-gr., 1 of I-gr.)	Many everywhere
1927	26,4 (83)	16,6	No cod caught	In quantities everywhere

cod in the Limfjord (see Blegvad ibid. 1916, List 1), and I shall discuss more closely in the following section the quantitative occurrence of these two species of fish in the Limfjord.

Fluctuations in the numbers of cod and viviparous blenny in the Limfjord 1908—1927.

Although the cod, in opposition to the plaice, spawns in the Limfjord it is by no means every year that a numerous stock of small cod (0-gr. in the bottom stage) occurs in these waters; as has been shown for many years by our fishing experiments, several years can elapse between each occurrence on a large scale of such small cod. Whether these are fry from this fjord's own cod stock or whether they originate from an immigration, e. g. through the Tyborøn Canal, like the plaice is still an open question; possibly future racial investigations will furnish valuable information in this respect.

The fishery statistics on the cod fishery in the Limfjord show very marked fluctuations, corresponding to the fluctuations in the occurrence of the cod fry; if a very abundant 0-gr. occurs in any given year the yield of the fishery will show an appreciable increase in the following three or four years; on the other hand there will be a very great fall in the yield when no cod fry have occurred for three consecutive years.

At the investigations conducted by the Biological Station in the Limfjord for the last 20 years, a very large number of fishing experiments have been carried out with the Eel-tog (see A. C. Johansen's article in the present report p. 74). If we calculate the number of Zoarces caught per 10 minutes' trawling with this implement, we shall get a general idea of the quantity of Zoarces on the soft bottom during these years. In Table 2 such a calculation has been made for the whole of the Limfjord to the west of Løgstør including all the large broads, i. e. the district A + B of the fishery statistics. The number of hauls is given in brackets, as a check on the reliability of the figures arrived at. In the next column is given the yield of the cod fishery in the same areas of the Limfjord, and in the next again will be found information regarding the cod which were caught simultaneously with the Zoarces at the fishing experiments with the Eel-tog. The number of cod caught at these experiments varies too much from place to place and from season to season to give a reliable picture of the quantity of cod in the Limfjord. In the last column will be found information regarding the occurrence of the large, black goby, *Gobius niger*, which like the viviparous blenny in the Limfjord lives to a large extent on small molluscs and worms (see Blegvad ibid. 1916, p. 53) and is eagerly sought by the cod.

Although only few hauls were made in 1912 and in the years of the war 1914—1917, the figures obtained for the number of Zoarces agree so well with the others that they certainly cannot be far wrong; the figure for 1914 (0,3) is however undoubtedly too low.

The yield of the cod fishery in the Limfjord during the years prior to 1908, and so far back as the information furnished by the fishery statistics, in terms of yield by weight, is available (1896) varied between 500 and 800 metric tons approximately per year. It will be seen from Table 2 that the yield in the first years after 1908 rose slowly from about 400 to about 600 tons, but that from 1912 a great fall in the yield took place until 1917 when a marked increase again occurred. This culminated in 1919 with over 1000 tons, but the yield thereupon again fell right up to 1927 which has produced the lowest yield up to now of all the years, viz., only 16,6 tons.

Fishing experiments with the Eel-tog afford a clear explanation of these great fluctuations. In 1908 a very numerous 0-gr. occurred whilst at the same time there were older year classes in the fjord. In 1909 on the other hand it is evident that no particularly numerous 0-gr. occurred but the numerous 1908 year class made itself already felt in the catches so that the total yield increased. This increase continued in 1910 when a less numerous 0-gr. at the same time occurred. In 1911 and 1912 no traces whatever were to be found of any 0-gr. apart from a few in Nissum Broad whither they had probably migrated from the North Sea; but the upgrowing cod of the 1908 year class had now become so heavy that in spite of the decreasing numbers they caused the yield of the fishery to culminate. As however no 0-group occurred either in 1913, 1914, or 1915 (still apart from Nissum Broad where in 1915 two small cod were caught), it is clear that the yield necessarily fell very rapidly; of the one really numerous year class for several years, i. e. 1908, there were now, owing to the fishery, practically none left. It will be noticed at the same time that the number of Zoarces which hitherto had been extremely small now began to increase, and the gobies also began to become numerous.

In 1916 just when the cod fishery produced the lowest yield which had hitherto been recorded for 20 years, namely only 38,7 tons, the Limfjord in the autumn teemed with cod of the 0-group, i. e. with cod too small to be caught with the fishermens' implements. But already in the following year 1917 they began to make themselves felt in the fishermens' catches, for which reason the fishery yield increased. At the same time the numbers of Zoarces and gobies culminated, the cod being for the most part still too small to eat such large animals[1]). But in the two following years, when the cod fishery rose to a record yield of over 1000 tons the numbers of Zoarces and gobies began to decline, and this decline continued right up to 1921. Whereas at the fishing experiments in 1917 no cod of the 0-group were found, the investigations in 1918, 1919, and 1920 showed that in each of these years an 0-group occurred; it was however of little importance in 1918 and 1919 whereas in 1920 it was fairly numerous although scarcely so numerous as the 1916 year class. But since 1920 no cod fry of any importance have appeared in the Limfjord. The yield of the fishery

[1]) It should be noticed that the smallest Zoarces including nearly all of the 0-group escape through the meshes of the Eel-tog; the figures in the table give therefore only the number of the larger Zoarces, from about 14 cm upwards.

has fallen year by year since 1922 being only 16,6 tons in 1927; there has never been such a small yield since fishery statistics on the yield by weight have been kept in the Limfjord. The cod stock has thus been diminished to a disquietening extent; even though adult cod are still found in the fjord, and even though no doubt the stock is recruited to a slight extent every year, this is far from providing a basis for an effective fishery.

Thus only a few especially abundant fry years, in particular 1908, 1916, and to a lesser extent 1920, have been the cause of the abundant fishing in the immediately following years. That there has been no plentiful fry year for cod in the Lim-

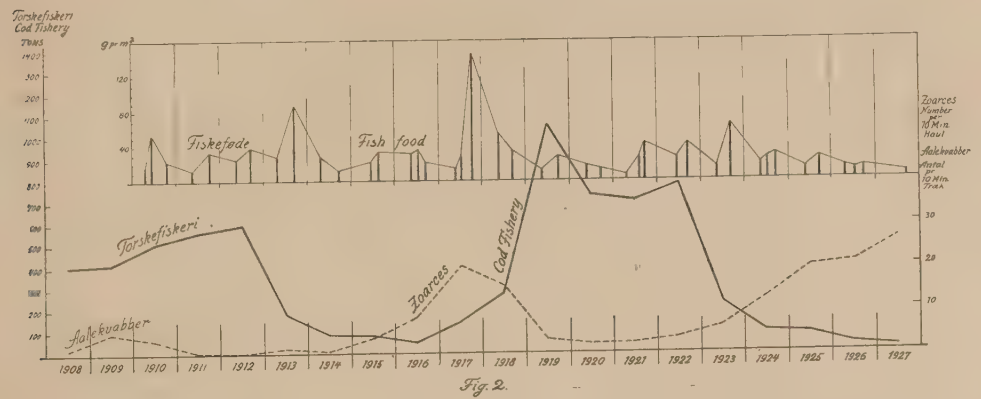

Fig. 2.

Yield of cod fishery and number of Zoarces caught per 10 minutes' haul with Eel-tog. Also the quantity of 1st class fish food in grams (rough weight) per sq. metre in the districts A + B of the Limfjord.

fjord for the last 8 years has been a catastrophe for the cod fishery there. At the same time Zoarces and gobies have spread over the entire fjord; in Fig. 2 a graphical presentment is given of the yield of the cod fishery and the number of Zoarces. The curves show clearly the negative correlation between the numbers of the Zoarces and those of cod. During the years prior to 1912 when there was a fairly large and more or less constant quantity of large cod in the Limfjord, the number of Zoarces was only small. Old Limfjord fishermen relate that when in the nineties fishermen came from the Isefjord in the summer to the Limfjord to fish for eels with hooks they found difficulty there in procuring a sufficient quantity of small Zoarces to serve as bait.

In Fig. 2 the curve is also plotted for the quantity of 1st class fish food in the districts A + B together of the Limfjord, i. e. a kind of common denominator for all the curves in Fig. 1 but with the areas of the separate broads taken into account in the calculations. This curve, composed as it is of a large number of fairly diverse curves, can of course only be considered as roughly comparable with the two other curves. It will however be noticed that the quantity of food in the years 1910—1912 was comparatively abundant in keeping with the fact that the number of Zoarces

was kept down by the large cod stock. 1913 was even a particularly good year, the cod stock having it is true decreased but consisting nevertheless of very large fish which succeeded in keeping the Zoarces in check; 1914 however was a bad year which was in keeping with a steady increase in the quantity of Zoarces. In 1915 and 1916, when the quantity of food was fairly normal, there must on the other hand have been particularly favourable conditions for the fry of the bottom invertebrates. 1917, when the fjord again teemed with cod of the I-group which at any rate were able to keep the young of the Zoarces away from the soft bottom (it must be kept in mind that the figures for Zoarces caught by the Eel-tog only hold good for the larger specimens) was a particularly good fry year for the food animals throughout the entire Limfjord. On the other hand there were no doubt physical causes which brought about the comparative paucity in 1918—1920 of the quantity of food. 1921—1923 were very abundant years, but 1924—1927 were all under the normal, which was in keeping with the great increase which was then taking place in the number of Zoarces.

All the facts mentioned here thus indicate that the decrease in the cod stock and the consequent increase in the numbers of Zoarces and gobies are factors which exert an important influence on the quantity of available plaice food in the Limfjord. It is probable that the unusually small and constantly decreasing quantity of plaice-food which was found in the Limfjord during the years 1924—1927 was due to the enormous increase in numbers of Zoarces and gobies during these same years, their consumption of food keeping down the quantity of food available.

As a means against the increase of Zoarces and gobies, a transplantation of young cod to the inner broads of the Limfjord deserves consideration. Whether such a transplantation would be directly remunerative is another question; but it must be borne in mind that a transplantation of cod would at the same time benefit both the plaice and the cod fishery. With the low prices for cod now prevailing such a transplantation would certainly not require a great outlay and the whole question should in any case be followed with close and unremitting attention, especially if the fall in the yields of both the cod and the plaice fisheries should still continue.

IV.

The Extent of the Annual Transplantations of Plaice in the Limfjord and the Yield resulting therefrom.

By

A. C. JOHANSEN

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1. Introduction.

In the eighties and beginning of the nineties of the past century plans were put forward for transplanting young plaice from Thyborøn Channel to the inner broads of the Limfjord. These plans were founded on the observations made by many Limfjord fishermen that numerous small plaice were found both in the Channel and in the neighbouring parts of the North Sea and Nissum Broad, whilst in the inner broads of the Fjord — especially in Visby, Thisted, Risgaarde, and Louns Broads — only a few fish occurred, although as a rule large ones. Among the men who were most active in their endeavours to bring about the realization of these plans may be mentioned the fishery superintendent Bloch, the fishery assistant Tranum and the fish dealers Chr. Mikkelsen and Mehlsen at Struer. The two latter sent in a petition to the Ministry for a State grant to defray the expenses of such a transplantation, and the sum of Kr. 2.400 was authorized to be used for this purpose. The transplantation was carried out during the spring and summer of 1892 and the Fiskeri-Beretning for the financial year 1891—92 contained the following reference to it:

"In consequence of the repeated complaints about the diminution of the plaice stock in the Limfjord, proposals have often been submitted to plant plaice fry, caught at Thyborøn where the fry come in from the sea, in the inner broads of the Limfjord.

A petition to the Ministry from the fish dealers Mikkelsen and Mehlsen at Struer for a State subsidy towards defraying the expenses of carrying out these experiments has therefore been granted on the condition that they are carried out under the supervision of the Jutland Fishery Patrol and that a definite number of fish are supplied at a fixed price. According to the report sent in by the Superintendent, flatfish fry were put out from March 21st till March 31st in Thisted Broad and Sallingsund at a cost of Kr. 412,50 and in addition:

May	5th	100	fourscore	plaice	in Venø Bay.
—	8th	69	—	—	- Sallingsund.
—	8th	139	—	—	- Risgaarde Broad.
—	15th	22	—		- Sallingsund.
—	15th	11	—	—	- Risgaarde Broad.
—	15th	43	—	—	between Fuur and Livø.
—	27th	74	—	—	in Visby Broad.

May	29th	97	fourscore	plaice in Thisted Broad.
June	4th	75	—	— - — —
—	9th	26	—	— - Visby Broad and Vilsund.
—	26th	28	—	— - Thisted Broad.
—	26th	29	—	— between Fuur and Livø.
—	28th	$22^1/_2$	—	— — — —
Aug.	28th	$59^1/_2$	—	— — — —
	Total	794	fourscore at a total cost of Kr. 1987,50".	

It will be seen from this report that in the year 1892 nearly 80.000 plaice were transplanted from the region around Thyborøn Channel to different broads in the Limfjord and that the cost was about 3 øre per fish.

If we assume that the cost of transplanting a definite quantity of plaice was the same in March as in May-August and that the distribution of the fish placed in Thisted Broad and Sallingsund was also the same, the numbers of fish placed in the different parts of the Fjord were as follows:

Venø Bay	c.	8.000 fish
Sallingsund	-	12.000 —
Visby Broad and Vilsund	-	8.000 —
Thisted Broad	-	25.000 —
Livø Broad	-	12.000 —
Risgaarde Broad	-	12.000 —
Total...	c.	77.000 fish

It will be seen from the above that when transplantation commenced, fish were caught in the region around Thyborøn Channel and placed not only in the north-western and eastern broads in the Fjord but also in Venø Bay and Sallingsund (see Fig. 1).

As it soon appeared that good results were being obtained from the transplantation, it was continued in the following years, the cost being for the most part defrayed by the State.

From an investigation of the plaice stock in the Limfjord in 1895 C. G. Joh. Petersen (1897) showed that plaice do not spawn in the Limfjord but immigrate thither from the North Sea and that this fact affords an explanation for the distribution of the fish in the Fjord. Only a few fish find their way into the inner broads whereas large quantities accumulate in the western parts of the Fjord, especially in Nissum Broad. He calculated from the results of precise fishing experiments with a fine-meshed seine that there were over 14 million young plaice in Nissum Broad in October 1895, i. e. a larger number than are caught annually in the entire Limfjord. There were also considerable quantities of young fish in Lavbjerg and

Fig. 1. The western part of the Limfjord.

Kaas Broads, and in Venø Bay. On the other hand marking experiments established the fact that in Thisted and Visby Broads practically no other plaice were found than those that had been put out in these waters.

Later investigations by Petersen (1909, 1922) and the present writer (1906, 1908, 1913, 1922) and Anton Fr. Bruun (1927) have proved that there is normally a surplus of small plaice in Nissum Broad, and from calculations based on fishing experiments with a small otter trawl ("Eel-tog"), described in Report XXIX from the Danish Biological Station for 1922, Petersen comes to the result that there were about 55 million plaice in the broads apart from the youngest year class (0-Gr.) and to some extent the next youngest year class in the shallows.

Petersen's calculation is based on the following argument: The number of plaice planted annually in Thisted Broad is known. If 100 times as many plaice are caught per haul and per hour with otter trawl in Nissum Broad as in Thisted Broad, the stock for the same area must be 100 times greater in Nissum Broad than in Thisted Broad.

Petersen mentions that the average figures obtained from the fishing experiments in Thisted Broad are not sufficiently accurate, as the many gill nets impede a thorough fishing of the whole area.

2. Extent of the transplantations.

The investigations carried out by Petersen afforded strong evidence in favour of the plantings commenced in Thisted and Visby Broads and he consequently advised the State to grant a larger sum towards the expense of planting so that it might be discovered by experiment how many fish could with advantage be put out in the different broads.

A new epoch in transplantations began in the year 1908, after a clause had been inserted in the Danish Fisheries Act of May 4th 1907 to the effect that up to Kr. 20.000 of the State Funds might be granted annually towards defraying the expenses of planting young fish in the Limfjord[1]). As shown below (Table 1), planting assumed considerably larger dimensions from the year 1908 and onwards.

As shown by Table 1, during the years 1908—28 1,3—2,7 million fish weighing 95.000—199.000 kilograms per year have been used for transplantation. The two war years 1917 and 1918 are however excluded. In the former of these two years transplantation was entirely discontinued, and in the latter fish were only put out in Thisted Broad. The extent of the transplantations was greatest during the years 1910—16 and in 1927 when 133.000—199.000 kilograms and 1,8—2,7 million fish were used annually for this purpose.

[1]) The Danish Saltwater Fisheries Act of June 2nd 1917 rendered possible the expenditure of a somewhat greater amount than Kr. 20.000 on the planting of young fish in the Limfjord, as the following clause was inserted in the Act: For putting out of fish fry and young fish in salt and fresh water as also for planting fish fry, the sum of Kr. 30.000 may be placed by the Exchequer at the disposal of the Ministry of Agriculture.

The cost of transplantation per kilogram of undersized fish was 10 and 11 øre in 1912 and 1913 respectively, and during the years 1918—28 has varied from 17 to 21 øre. The cost of transplantation per fish has been 0,8—1,1 øre during the years 1902—16 and 1927—28, and 1,2—1,7 øre during the period 1918—26.

The cost of transplantation has in the main been defrayed by the State. That the local fishermen's associations have only contributed a comparatively small amount is due firstly to their having only small funds at their disposal and secondly to the fact that all Danish fishermen have the right to fish in the regions where fish are planted. In general however it is only those fishermen who live on the shores of the Limfjord who avail themselves of this right.

The fish to be used for planting are caught as a rule from small boats with the Danish seine, the mesh of which must not be less than 39 mm. from knot to knot. The length of the lines must not exceed 400 metres for each arm of the seine. The small boats deliver the fish to well smacks which transport the fish to the spot where they are to be set free. During transference from the small boats to the well

Table 1. Extent of the transplantation of plaice in the Limfjord during the years 1902—1928.

Year	Weight in kg.	No. of fish	Average weight per 100 fish in kg.	Cost of transplantation				
				Contribution from fishery associations in kroner	State contribution in kroner	Total in kroner	Cost in øre	
							per kg.	per fish
1902.....	c. 20.320[1])	254.000	..	..	..	2.800	..	1,1
1903.....	c. 27.040[1])	338.000	..	1.000	2.700	3.700	..	1,1
1905.....	c. 23.600[1])	295.000	..	..	..	3.200	..	1,1
1908.....	c. 111.360[1])	1.392.000	..	500	15.300	15.800	..	1,1
1909.....	c. 128.000[1])	1.600.000	..	700	17.300	18.000	..	1,1
1910.....	c. 147.200[1])	1.840.000	..	700	19.735	20.435	..	1,1
1911.....	c. 145.680[1])	1.821.000	..	750	19.735	20.485	..	1,1
1912.....	198.540	2.206.000	9,00	250	19.600	19.850	10	0,9
1913.....	188.360	2.216.000	8,50	350	19.600	19.950	11	0,9
1914.....	c. 176.480[1])	2.206.000	..	250	19.600	19.850	..	0,9
1915.....	c. 176.480[1])	2:206.000	..	250	19.600	19.850	..	0,9
1916.....	c. 178.240[1])	2.228.000	..	450	19.600	20.050	..	0,9
1917.....	0	0	..	0	0	0	..	..
1918.....	23.257	251.000	9,25	0	4.400	4.400	19	1,7
1919.....	116.470	1.456.000	8,00	2.850	21.900	24.750	21	1,7
1920.....	96.534	1.332.000	7,25	735	21.900	22.635	23	1,7
1921.....	95.316	1.315.000	7,25	450	21.900	22.350	23	1,7
1922.....	108.412	1.735.000	6,25	650	21.900	22.550	21	1,3
1923.....	112.000	1.867.000	6,00	500	21.900	22.400	20	1,2
1924.....	115.885	1.854.000	6,25	600	21.900	22.500	19	1,2
1925.....	101.363	1.352.000	7,50	50	22.250	22.300	22	1,6
1926.....	102.500	1.366.000	7,50	50	22.500	22.550	22	1,6
1927.....	132.647	2.653.000	5,00	50	22.500	22.550	17	0,8
1928.....	116.053	1.934.000	6,00	50	20.100	20.150	17	1,0

[1]) Average weight estimated at 8 kilograms per 100 fish.

smacks, the fish are subjected to the scrutiny of the Fisheries officials who check their size, quantity, and vitality. From the year 1928 inclusive the regulation has in addition been adopted that the fish shall also be weighed under due supervision at the place of liberation, and the price agreed upon shall only be paid for fish in lively and good condition. The capture of the fish and their transport are paid for separately. In 1928, 10 øre per kilogram were for instance paid for capture and 9 øre per kilogram for transport.

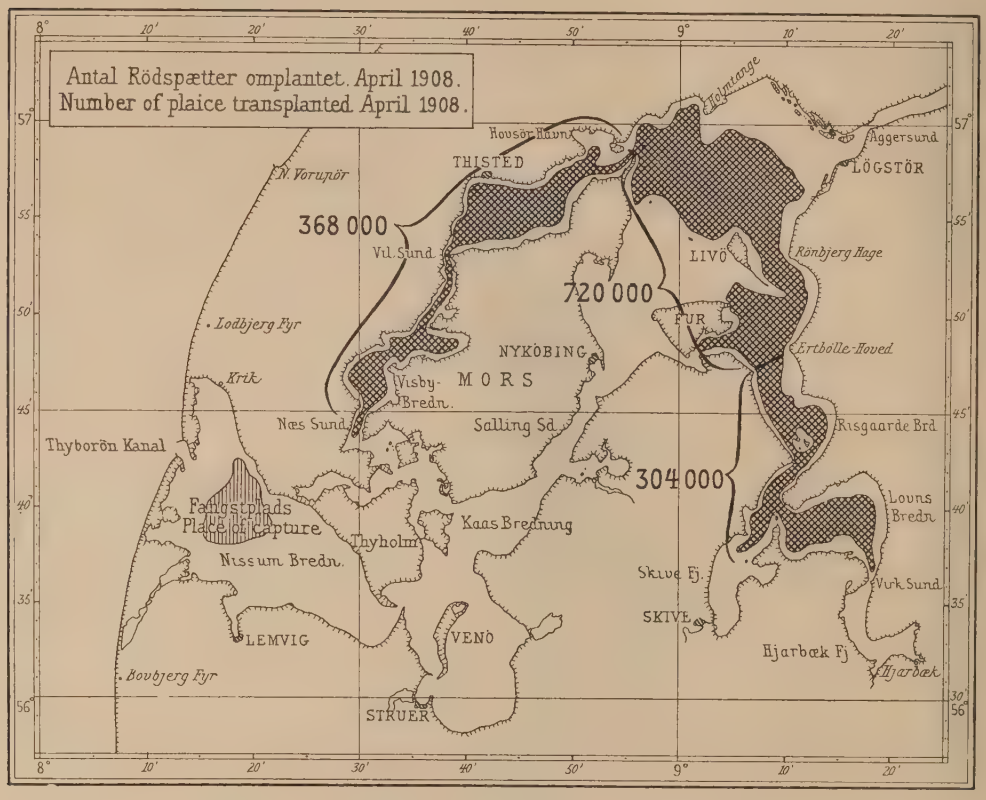

Fig. 2. Distribution of plaice transplanted. April 1908.

Distribution of the fish in the different parts of the Limfjord.

As mentioned above, plaice were liberated in the following localities in the Fjord during the first stage of the transplantations: Venø Bay, Sallingsund, Visby Broad and Vilsund, Thisted Broad, Livø Broad, and Risgaarde Broad. Through Petersen's investigations in the nineties it soon became apparent that there was no lack of young fish either in Venø Bay or in Sallingsund, and the putting out of fish in these localities was quickly discontinued[1]), whilst Hvalpsund and Louns Broad were included amongst the planted areas.

[1]) It has occurred that fishermen have transplanted a small number of plaice from Nissum Broad to Venø Bay at their own expense also in recent years.

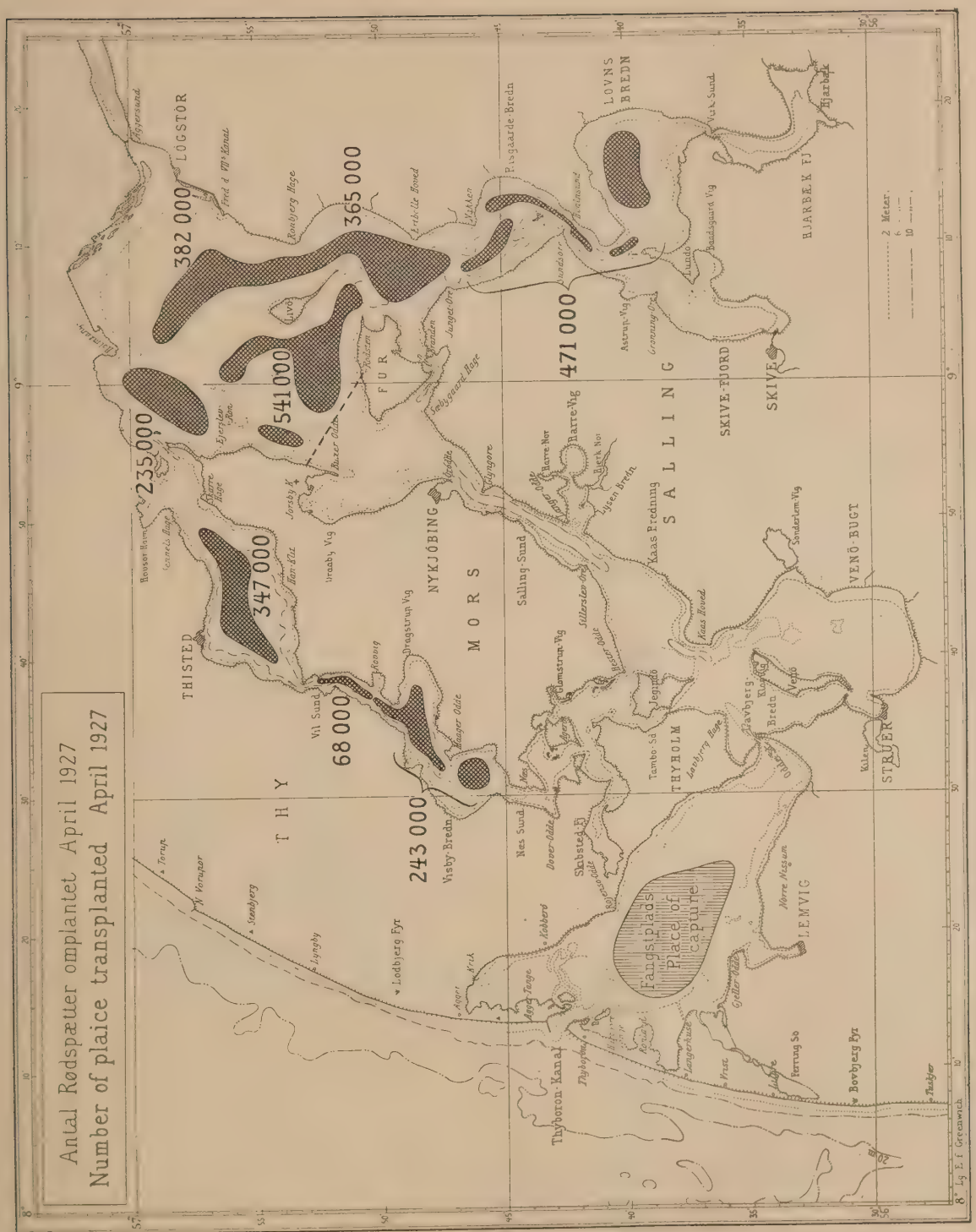

Fig. 3. Distribution of plaice transplanted. April 1927.

Fig. 4. Distribution of plaice transplanted. April 1928.

Table 2 shows the distribution of the fish in a series of different years within the period 1901—28, and Figs. 2—4 show the extent of the planted areas and the quantity of fish liberated during the years 1908, 1927, and 1928[1]).

It will be seen from Table 2 that during the period extending approximately from 1902 till 1905 no more plaice were liberated in Livø Broad than in Thisted-Visby Broads, and only about $1^1/_2$ times as many plaice in Livø Broad as in Risgaarde and Louns Broads, including Hvalpsund. A change took place in this respect when the more extensive plantings commenced in 1908. During the period 1908—28 more fish have been placed annually in Livø Broad than in all the other broads together (apart from the two war years 1917 and 1918). During the period 1920—28

Table 2. Distribution of the fish placed in different parts of the Limfjord during the years 1901—28.

Year	Kilograms			No. of fish in thousands		
	Thisted and Visby Broads	Livø Broad	Risgaarde Br. Hvalpsund Louns Br.	Thisted and Visby Broads	Livø Broad	Risgaarde Hvalpsund Louns Br.
1901	c. 10.160[1])	?	?	127	?	?
1902	c. 11.360[1])	c. 8.960[1])		142	112	
1903	c. 9.200[1])	c. 10.720[1])	c. 7.120[1])	115	134	89
1904	c. 9.200[1])	?	?	115	?	?
1905	c. 9.280[1])	c. 8.880[1])	c. 5.440[1])	116	111	68
1906	c. 10.960[1])	?	?	137	?	?
1907	c. 10.160[1])	?	?	127	?	?
1908	c. 29.440[1])	c. 57.600[1])	c. 24.320[1])	368	720	304
1909	c. 44.000[1])	c. 84.000[1])		551	1.049	
1910	c. 45.040[1])	c. 102.160[1])		563	1.277	
1911	c. 45.440[1])	c. 100.240[1])		568	1.253	
1912	62.010	136.530		689	1.517	
1913	59.500	128.860		700	1.516	
1914	c. 55.520[1])	c. 120.960[1])		694	1.512	
1915	c. 55.120[1])	c. 121.360[1])		689	1.517	
1916	c. 55.000[1])	c. 121.360[1])		711	1.517	
1917	0	0	0	0	0	0
1918	23.257	0	0	251	0	0
1919	27.058	57.412	21.647	339	718	271
1920	23.029	55.661	17.059	318	768	235
1921	23.029	54.462	17.059	318	751	235
1922	26.442	61.722	19.231	423	988	308
1923	27.000	65.000	20.000	450	1.083	333
1924	27.604	66.361	20.833	442	1.062	333
1925	24.318	58.863	18.182	324	785	242
1926	25.454	58.863	18.182	339	785	242
1927	32.941	76.177	23.529	659	1.524	471
1928	29.474	66.053	20.526	491	1.101	342

[1]) Average weight estimated at 8 kg. per 100 fish.

[1]) The Fishery Superintendent Jørgensen has kindly furnished us with information regarding the distribution of the fish transplanted from Nissum Broad in 1927 and 1928.

more than twice as many plaice have been put out in Livø Broad as in Thisted and Visby Broads and more than three times as many fish as in Risgaarde and Louns Broads.

3. Yield resulting from the transplantations.

In estimating the yield resulting from the transplantations of plaice a distinction must be made between two different categories of localities:

1) The localities where the natural stock is very small and almost devoid of importance for the fishery.
2) The localities where, in any case at certain times, there is a natural stock which is of considerable importance for the fishery.

Thisted Broad and Visby Broad with Vilsund belong to the first category; Livø Broad and Risgaarde Broads to the second. We can of course make a far more reliable estimate of the yield from the localities in the first category than in the second and we will therefore first consider Thisted and Visby Broads.

Yield resulting from the plantings in Thisted and Visby Broads.

In Table 3 is given a statistical survey of the plantings and the fishery yield in the same year in which planting has taken place in Thisted and Visby Broads including Vilsund. As regards the years 1901—17, the table is based partly on data published by C. G. Joh. Petersen in Report XXIX from the Danish Biological Station (1922) and partly on data kindly placed at my disposal by the Fisheries Board. As regards the years 1918—27 the table is based on information contained in the "Fiskeri-Beretning". The fishery yield shown in the table is based mainly on reports sent in from the Fishermen's Association for Thisted and the surrounding district to the Jutland Fishery Patrol[1]).

Table 3 shows clearly that there is a connection between the quantity of the plaice put out and the yield of the plaice fishery in the same year in which planting takes place. The entire yield resulting from the planting is not however obtained in the same calendar year in which the fish are planted. It will thus be seen that in 1917 there was a fishery yield of 27 tons, although no fish were planted during this year. The yield was obviously derived from the fish planted in 1916 and perhaps also — although to a very slight degree — from the planting in 1915. From a comparison between the size of the yield in 1917 with that in previous years and from a series of observations of the distribution of the yield in the first ten months after

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[1]) The yield of the "Flynder"-fisheries given in the Fiskeri-Beretning, including both plaice and flounders, differs considerably in certain years and especially during the period 1910—16 from the yield given in Table 3, which will appear from the summary below:

Yield of the "Flynder"-fisheries in Thisted and Visby Broads.

1910	170 tons	1914	98 tons
1911	170 —	1915	88 —
1912	180 —	1916	52 —
1913	85 —		

Table 3. Quantity of plaice transplanted, and yield of the plaice fishery in Thisted and Visby Broads during the years 1901—27.

Year	Plaice put out		Catch	
	Kg.	No. of fish in thous.	Weight in tons	Value (Kr. 1000)
1901	c. 10.160	127	c. 39	23
1902	c. 11.360	142	c. 36	15
1903	c. 9.200	115	35	19
1904	c. 9.200	115	21	14
1905	c. 9.280	116	30	18
1906	c. 10.960	137	45	29
1907	c. 10.160	127	42	28
1908	c. 29.440	368	102	67
1909	c. 44.000	551	149	98
1910	c. 55.040	563	142	91
1911	c. 45.440	568	100	64
1912	62.010	689	119	71
1913	59.500	700	113	74
1914	c. 55.520	694	129	78
1915	c. 55.120	689	122	102
1916	c. 55.000	711	67	81
1917	0	0	27	32
1918	23.257	251	36	47
1919	27.058	339	35	66
1920	23.029	318	35	69
1921	23.029	318	41	62
1922	26.442	423	35	47
1923	27.000	450	54,5	76
1924	27.604	442	65	91
1925	24.316	324	49	58
1926	25.454	339	25,5	31
1927	32.941	659	30	36

planting has taken place[1]), it can be estimated that about three quarters of the yield of the transplantations is obtained on an average in the same year that the transplantation is carried out, whilst about one quarter is obtained in the following calendar year[2]). We miss, however, for most of the years monthly statistics of the yield.

Such a distribution of the effect of planting on the yield in two different calendar years is taken into account in Fig. 5, which illustrates the connection between planting and the yield. The correlation is here very striking and a calculation shows that the correlation coefficient r has a value of 0,81 while $\sigma_r = 0{,}067$. The figure shows however very clearly that the yield in recent years has been considerably smaller than during the previous period 1901—16 in proportion to the quantity

[1]) Published in various annual series of the Fiskeri-Beretning.

[2]) In the years when the transplanted fish have been comparatively large and their growth comparatively rapid, a comparatively large percentage of the yield is obtained in the same calendar year in which planting takes place

of fish planted. If we calculate the yield in tons for each ton of fish put out we obtain the following result:

For the period	1901—07	averagely	3,5	tons
— —	1908—16	—	2,2	—
— —	1918—27	—	1,6	—

The yield in terms of weight per ton planted fish in the last period is thus less than half that obtained in the first period.

The yield in terms of value resulting from the transplantations may be con-

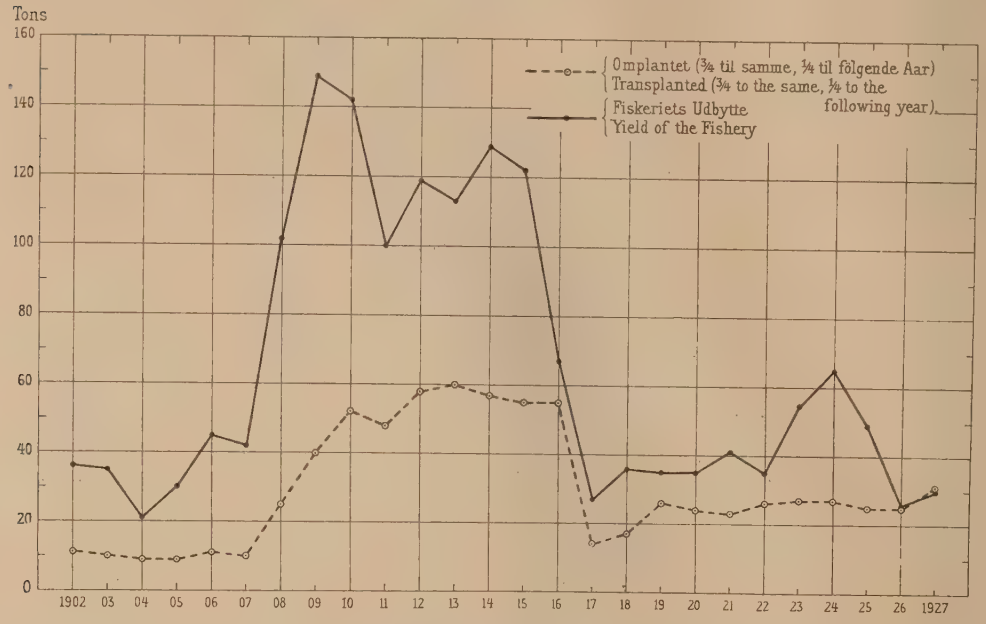
Tons
160
140
120
100
80
60
40
20
0
Omplantet (¾ til samme, ¼ til følgende Aar)
Transplanted (¾ to the same, ¼ to the following year)
Fiskeriets Udbytte
Yield of the Fishery
1902 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 1927

Fig. 5. The amount of plaice transplanted and the yield of the fishery in Thisted and Visby Broads in the years 1902—27.

sidered on the whole as extremely satisfactory. The net yield is found by subtracting from the yield shown in Table 3 the cost of transplantation, which for the period 1908—27 amounted to c. Kr. 5000—6000 per year (cp. Table 1 and Table 3). The average net yield for the period 1908—16 amounted thus to c. Kr. 75.000 per year, for the period 1918—24 to c. Kr. 60.000, but during the years 1926—27 to only c. Kr. 28.000. It is however assumed in this calculation that there is no natural immigration into Thisted and Visby Broads, which in reality does occur, but the effect of this immigration is minute in proportion to the stated yield.

Yield resulting from the plantings in Livø, Risgaarde and Louns Broads, including Hvalpsund.

In Table 4 a survey is given showing the quantity of plaice put out in Livø, Risgaarde and Louns Broads, and in Hvalpsund, and the yield of the fishery in

the same broads and Sallingsund (the so-called District B in the Limfjord) during the years 1902—27. The western parts of Livø Broad and Sallingsund are included in the summary of the yield as many of the fish put out in the central, northern, and eastern parts of Livø Broad, and in Risgaarde and Louns Broads are caught there. In comparing the quantity of the fish put out with the yield of the fishery, it is best to disregard the years 1902—04, as an abnormally great immigration into the eastern broads occurred in 1902—03, the effects of which could probably still be traced in 1904. It will also be best to disregard the year 1927, as the weather was abnormally bad when planting took place in April 1927 and as a consequence the

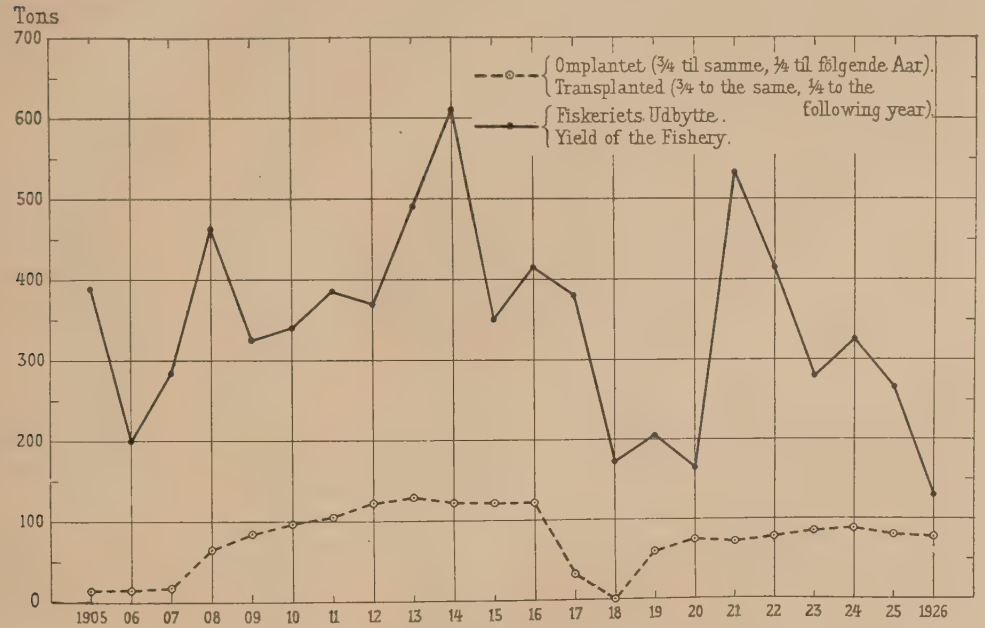

Fig. 6. The amount of plaice transplanted and the yield of the fishery in Distrikt B in the years 1905—26.

fish were undoubtedly not brought into the eastern broads in viable condition in such great numbers as stated. If we compare the weight of the fish planted with the yield of the fishery for the period 1905—26 and assume (as in the case of Thisted and Visby Broads) that three quarters of the yield resulting from the planting was obtained in the same calendar year in which planting took place and one quarter in the succeeding calendar year (see Fig. 6) we obtain, by calculating the correlation, $r = 0{,}46$ and $\sigma_r = 0{,}17$. It is thus extremely probable that planting has had an appreciable effect on the yield, but there is no complete proof of it. The natural immigration into these parts of the Fjord fluctuates greatly in extent, at times to a very marked degree, and this helps to confuse the effects of planting. In respect to the northern and eastern parts of Livø Broad ("Hannæs and Løgstør Broads"), Risgaarde and Louns Broads, including Hvalpsund, we can estimate that the yield

Table 4. Quantity of plaice put out, and yield of the fishery in District B of the Limfjord during the years 1902—27.

Year	Plaice put out		Catch	
	Kg.	No. of fish in thous.	Weight in tons	Value in Kr.
1902	c. 8.960	112	881	223.470
1903	c. 17.840	223	810	283.850
1904	c. 16.000[1])	c. 200[1])	391	150.950
1905	c. 14.320	179	391	130.980
1906	c. 16.000[1])	c. 200[1])	200	92.900
1907	c. 16.000[1])	c. 200[1])	285	132.600
1908	c. 81.920	1.024	462	201.500
1909	c. 84.000	1.049	324	159.320
1910	c. 102.160	1.277	341	165.200
1911	c. 102.240	1.253	384	174.340
1912	136.653	1.517	369	181.170
1913	128.860	1.516	489	224.270
1914	c. 120.960	1.512	610	251.140
1915	c. 121.360	1.517	350	208.500
1916	c. 121.360	1.517	416	419.510
1917	0	0	380	234.680
1918	0	0	173	111.700
1919	79.059	989	204	185.025
1920	72.720	1.003	167	200.160
1921	71.521	986	533	433.980
1922	80.953	1.296	414	274.160
1923	85.000	1.416	279	216.580
1924	87.194	1.395	325	237.690
1925	77.045	1.027	264	160.150
1926	77.045	1.027	131	64.720
1927	99.706	1.995	143	..

[1]) Estimated.

there resulting from the transplantations must be smaller than that obtained in Thisted and Visby Broads, even if we assume that the whole yield of the plaice

Table 5. Weight of the plaice put out, and yield of the fishery in Risgaarde Broad, Hvalpsund, and Louns Broad during the years 1919—27.

Year	Plaice put out	Catch	
	Kg.	Kg.	Value in Kr.
1919	21.647	11.500	12.600
1920	17.059	16.000	19.200
1921	17.059	14,525	13.000
1922	19.231	14.600	11.680
1923	20.000	9.000	9.000
1924	20.833	11.000	11.000
1925	18.182	16.800	16.800
1926	18.182	1.600	1.600
1927	23.529	12.500	10.000

fishery in these localities is derived from the fish planted (see Tables 6 and 7). For each ton of transplanted fish only 0,6 ton of marketable fish have been recaptured in these localities during the period 1919—27, i. e. about one third of the yield obtained during the same period in Thisted and Visby Broads. In recent years the yield has been comparatively small just as in Thisted and Visby Broads. The average annual yield in terms of value during this period has been c. Kr. 37.000, whilst the annual cost of transplantation has amounted to c. Kr. 9000. On the other hand it may be pointed out that the fish distributed in the above localities are partially recaptured in the more western parts of the Limfjord which thus profits from the sojourn of the fish in the eastern broads. The marking experiments carried out by the Danish Biological Station in 1927 and 1928 have shown that the fish placed in Thisted and Visby Broads are far more stationary than the fish placed in the eastern broads of the Fjord.

The effect of the plantings is probably also less pronounced in the central parts of Livø Broad than in Thisted and Visby Broads.

Table 6. Weight of the plaice put out, and yield of the fishery in Løgstør and Hannæs Broads during the years 1919—27.

Year	Plaice put out	Catch	
	Kg.	Kg.	Value in Kr.
1919.....	16.471	16.200	21.000
1920.....	22.710	18.000	24.600
1921.....	22.176	57.000	53.000
1922.....	25.481	57.800	50.620
1923.....	26.250	22.020	22.700
1924.....	27.083	27.600	30.300
1925.....	23.863	11.900	11.900
1926.....	23.863	4.100	4.100
1927.....	30.883	9.250	7.400

4. Causes of the yield from the transplantations in the Limfjord having been smaller in recent years than formerly.

As shown in Chapter 3, the yield resulting from the transplantations in the Limfjord in recent years — and especially in the years 1926 and 1927 — has been considerably smaller than formerly. If we consider the yield in tons for each ton of fish planted, we obtain, as already mentioned, for Thisted and Visby Broads:

For the period 1901—07 averagely 3,5 tons
— — 1908—16 — 2,2 —
— — 1918—27 — 1,6 —

If we ask why the yield in recent years has been proportionately smaller than formerly, we shall at once obtain some enlightenment by studying Table 7, which gives the number of plaice put out annually and recaptured later as marketable in

three different periods, viz. 1899—1907, 1908—16, and 1918—27. The table namely shows that during the period 1899—1907 on an average about 65 per cent. of the fish put out were captured as marketable, during the period 1908—16 53 per cent., and during the period 1919—27 only 27 per cent. It is possible that the cause of the fall in the catch from the period 1899—1907 till the period 1908—27 is partially due to the fact that during the latter period a considerably higher size limit (c. 30,5 cm.) was in force than during the former (c. 25,6 cm.), but the same size limit was in force during the period 1918—27 as for the period 1908—16. The marked fall in the

Table 7. Number of fish planted and recaptured in Thisted and Visby Broads during the years 1899—1927.

Year	Number planted	Number caught as marketable fish	Weight in Kg. per 100 fish	Percentage of recaptures	Percentage of loss
1899	107.000	70.000	..	65,4	34,6
1901	109.840	87.200	..	79,4	20,6
1902	141.560	81.340	..	57,5	42,5
1903	114.800	79.196	..	69,0	31,0
1904	115.000	47.000	..	40,9	59,1
1905	115.600	65.747	..	56,9	43,1
1906	137.000	101.000	..	71,4	28,6
1907	124.480	95.000	..	76,3	23,7
1899—1907	965.280	626.483	..	64,6	35,4
1908	368.000	254.000	40	69,0	31,0
1909	551.000	397.000[1])	..	72,1	27,9
1910	563.000	379.000[1])	..	67,3	32,7
1911	568.000	269.000[1])	..	47,0	53,0
1912	689.000	309.000	38,5	44,8	55,2
1913	700.000	323.000	35	46,1	53,9
1914	694.000	397.000	32,5	57,2	42,8
1915	689.000	287.000	42,5	41,7	58,3
1916	711.000	244.000	27,5	34,3	65,7
1908—16	5.533.000	2.859.000	..	53,3	46,7
1918	251.429	68.571	52,5	27,3	72,7
1919	338.229	84.848	41,25	25,1	74,9
1920	317.647	89.290	38,75	28,1	71,9
1921	317,647	94.286	43,75	29,7	70,3
1922	423.077	83.879	41,25	19,8	80,2
1923	450.000	132.121	41,25	29,4	70,6
1924	441.667	162.000	40	36,7	63,3
1925	324.240	139.143	35	42,9	57,1
1926	339.387	63.875	40	18,8	81,2
1927	658.000	75.250	40	11,4	88,6
1918—27	3.861.323	993.263	..	26,9	73,1

[1]) Calculated according to an average weight of 37,5 Kg. per 100 fish.

percentage of recaptures in the course of years must thus undoubtedly be due in the main to the increasing intensity with which fishing has been carried on. During the period 1899—1907 only 35 per cent. of the fish planted were lost before being captured as marketable fish, but during the period 1918—27 73 per cent. of the fish were lost. In 1926 and 1927 the percentage of loss has even reached the height of 81,2 and 88,6 respectively.

The marking experiments with plaice carried out in the Limfjord in April 1927 and April 1928 enable us to form some conception of what a great percentage of the fish planted is lost by their being caught too early. These experiments were conducted in conjunction with the ordinary transplantations from Nissum Broad to the inner broads of the Fjord, and the fish to be marked were taken from the well smacks transporting the fish to the place of liberation.

Tables 8 and 9 show what percentages were caught in each of the first months after liberation during the experiments in April 1927 and April 1928:

Table 8. Percentages of marked plaice recaptured in each of the first months after Liberation.
Experiments in April 1927.

	Visby Broad 50 fish liber. 22-4-27	Thisted Broad 100 fish liber. 22-4-27	Livø Broad 100 fish liber. 23-4-27	East of Fur 50 fish liber. 23-4-27	Risgaarde Br. 100 fish liber. 23-4-27
	%	%	%	%	%
April-May 1927....	12	17	19	10	12
June —	10	19	16	12	5
July —	10	19	9	6	5
August —	0	6	2	2	3
September —	0	0	0	2	0

Table 9. Percentages of marked plaice recaptured in each of the first months after Liberation.
Experiments in April 1928.

	Visby Broad 50 fish liberated 20-4-28	Thisted Broad 100 fish liberated 20-4-28	Livø Broad 100 fish liberated 19-4-28	Løgstør Broad 100 fish liberated 19-4-1928	Risgaarde Broad 50 fish liberated 18-4-1928	Louns Broad 100 fish liberated 18-4-28
	%	%	%	%	%	%
April-May 1928.	12	59	35	23	16	3
June — .	14	9	11	15	12	3
July — .	16	12	4	11	6	7
August — .	6	4	1	4	0	7

These summaries show that a very large percentage of the fish planted are caught shortly after liberation, especially in Thisted and Livø Broads. These fish

are caught in gill nets, pound nets and eel-seines at a time when they have not yet attained the legal size limit. Fishing with the Danish plaice seine (Snurrevaad) is not permitted in the planted areas until the 1st or 15th of October. It is true that fishermen are required to liberate the fish after capture if they are undersized but many are injured by capture, and when fish are caught in gill nets, a number of them are killed by whelks, *Nassa reticulata* and *Asterias rubens* etc. It may be assumed that a larger percentage of the marked fish are caught in gill nets than the unmarked, as the label easily becomes entangled in the net and prevents the fish from escaping, but a number of the unmarked undersized fish are nevertheless caught in gill-nets. It would undoubtedly be of benefit to forbid the use of this appliance in the planted areas for the first months after the planting has been carried out, e. g. until the end of July.

In 1926 and 1927 the yield resulting from the transplantations was particularly poor, which is possibly due to some extent to the fact that the animals especially favoured by plaice were present only in small quantities during these years (see H. Blegvad and Aage J. C. Jensen in this report Nos. III and V). The poor yield in recent years is not due to the attacks of cod, the stock of this species in the Limfjord having been unusually small during these very years.

5. Is it more profitable to plant relatively small or relatively large plaice in the Limfjord?

The cost of fish for planting is the same per kilogram whether comparatively small or comparatively large undersized plaice are used, and at certain times small marketable fish can be purchased at about the same price per kilogram as undersized fish. It is thus a question of some importance as to which size category of fish it is most profitable to plant. If we choose small fish we can plant a large number, but they are on the other hand more liable to be caught before they attain the size limit and more susceptible to attacks from their enemies than the larger fish.

Table 10. Yield per ton of planted fish of various sizes during the years 1918—1927. Thisted and Visby Broads.

Weight per 100 planted fish	Yield per ton of planted fish	Year
Kg.	Tons	
5,00	0,9	1927
6,00	2,0	1923
6,25	1,3	1922
6,25	2,4	1924
7,25	1,5	1920
7,25	1,8	1921
7,50	2,0	1925
7,50	1,0	1926
8,00	1,3	1919
9,25	1,5	1918

We shall attempt to contribute to the solution of this problem by calculating in the case of Thisted and Visby Broads how large the yield per ton of planted fish has been in each separate year within the period 1918—27. It will be seen from Table 10 that in the four years when the planted fish have been small, viz. 5,0—6,25 kg. per 100, the average yield per ton of planted fish has been 1,65 tons. In the six years when the planted fish have been comparatively large, from 7,25 to 9,25 kg. per 100, the average yield per ton of planted fish has been 1,5 tons. When in addition it may be assumed that by planting 1 ton of small fish a larger portion of the yield is obtained on an average in the following calendar year than by planting 1 ton of large fish, our calculations tend to show that the small fish planted in the above-mentioned broads and during the stated period have produced the larger yield. It must however be pointed out that during the period 1922—27 there have only

Table 11. Distribution according to length of fish for transplantation from Nissum Broad and Thyborøn. April 1928.

Place caught..	Nissum Broad and Thyborøn	Nissum Broad	Nissum Broad and Thyborøn	Nissum Broad	Nissum Broad and Thyborøn	Nissum Broad and Thyborøn
Length in cm.						
8	..	..	..	..	..	..
9	..	..	..	..	..	..
10	..	..	1	..	..	..
11	..	5	4	..	..	..
12	3	3	11	3	1	..
13	6	4	18	6	5	2
14	15	17	20	16	15	6
15	28	49	47	12	33	9
16	33	46	63	18	35	8
17	19	36	61	24	41	20
18	12	29	48	13	53	12
19	3	11	29	14	46	16
20	4	14	12	8	55	11
21	1	6	13	8	54	11
22	3	7	12	11	50	17
23	..	5	10	6	44	13
24	..	3	3	5	49	19
25	..	..	3	2	15	6
26	..	1	1	..	2	1
27	..	..	..	..	2	..
28	..	..	1	..	..	..
29	..	..	..	..	..	..
30	..	..	1	..	..	..
Total....	127	236	358	146	500	151
Weight in kg. per 100 fish	3,7	5,1	5,3	6,2	8,4	9,3
Mean length in cm.	16,0 + 0,5	16,8 + 0,5	17,0 + 0,5	17,8 + 0,5	19,7 + 0,5	19,8 + 0,5

been comparatively few enemies of plaice in Thisted and Visby Broads, the cod stock having been unusually small and the other animals not attacking the plaice there to any considerable extent until the latter are caught in the fishing appliances. It is possible that a similar answer to the question enunciated above would not be returned in the case of all our waters.

A summary is given in Table 11 showing the distribution according to length in some samples of "small" and "large" fish for planting from Nissum Broad.

6. The size of the plaice stock in the different parts of the Limfjord, and the yield of the fishery in relation to the size of the stock.

A series of fishing experiments were carried out from the steamer "Japetus Steenstrup" in September 1926, April and July 1927, and April and June-July 1928 in order to obtain further information with respect to the question of the size of the plaice stock in Nissum Broad and in the other parts of the Limfjord. The fishing appliance used was a fine-meshed otter trawl, the so-called Eel-tog, which has been used by the Danish Biological Station for a number of years. This appliance is an almost rectangular fine-meshed trawl devoid of arms and provided with a chock. The trawl is 3,5 metres broad and 0,9 metres high at the mouth, whilst the length is 8,5—9 metres. The meshes are 18 mm. from knot to knot in front and 15 mm. in the bag behind. The otter boards, shod with iron, are 123 cm. long, 72 cm. high, 3,5 cm. thick above and 5 cm. thick below. The lines between the boards and the trawl are 20 metres long, and the lower line is provided with bass tassels. The towing bridle is 40 metres long. The trawl is dragged at a speed of about one sea-mile per hour and when the appliance is drawn over the bottom the two lines in the towing bridle form an angle which as a rule varies between 25° and 30°. The distance between the boards varies from c. 17 to c. 21 metres. If the boards draw closer together this is as a rule due to plants or bottom material entering the net in large quantities.

In general hauls are made of 30 minutes' duration and the mean average surface scoured by the boards, bass lines, and foot rope of the trawl during this time then amounts to c. 18.000 square metres, whilst the area scoured by the foot rope of the trawl alone is only c. 3.000 square metres. In places where the plaice are dense, hauls of shorter duration than 30 minutes are often taken.

In the following calculations of the number of plaice in the different regions of the Limfjord are made. The areas comprised are in every case outside the 4 metre line. The following values for the areas were found by Aage J. C. Jensen by measuring with planimeter a map of scale 1 : 130.000. (For the boundary lines of the regions compare Fig. 1, p. 57).

Areas of the different regions of the Limfjord outside the 4 metre line.

Nissum Broad	148 sq. km.
Lavbjerg Broad	40 —

Venø Bay	60 sq. km.
Kaas Broad	40 —
Sallingsund	24 —
Livø Broad	338 —
The portion of Livø Broad W. of the line Jörsby-Rødsten	54 —
— — - — — named Løgstør and Hannæs Broads.	156 —
Risgaarde Broad including Hvalpsund	48 —
Louns Broad	44 —
Thisted Broad	72 —
Visby Broad	42 —

The observations on which we base our calculations of the size of the stock in the different parts of the Limfjord are as follows:

1) In April 1928, before the plaice from Nissum Broad were put out, only 0,2 plaice were caught with eel-tog per 30 minutes' haul (at 13 stations, Fig. 9) in Thisted and Visby Broads. After the planting of 491.000 fish, 9,3 were caught with the same appliance per 30 minutes' haul (at 12 stations, Fig. 10). The experiments thus showed that the number of plaice in Thisted-Visby Broads before planting took place was minute.
2) The average catch of plaice in Thisted Broad in April 1927, after 347.000 plaice had been planted, was 6,6 per 30 minutes' haul[1]) (Fig. 7). The area of Thisted Broad being 72 square kilometres and that of Thisted-Visby Broads 114, 12,1 plaice were caught per 30 minutes' haul per million fish placed in Thisted-Visby Broads.

The average catch in Thisted-Visby Broads in April 1928, after 491.000 plaice had been put out, was 9,3 per 30 minutes' haul. The catch per million fish planted was thus 18,9 per 30 minutes' haul.

The mean catch for the two years 1927 and 1928 was thus 15.5 plaice per million planted. In Thisted-Visby Broads there are in an area of 18.000 square metres if a million plaice are present in the Broads $\frac{1.000.000 \times 18.000}{114.000.000} = 158$ plaice.

From this it may be calculated that the trawl captures about one tenth of the plaice present in the area swept by the boards, bass lines and trawl, and about six tenths of the plaice in the area scoured by the foot rope of the trawl itself[2]).

The average catch per 30 minutes' haul in Nissum Broad was as follows:

April 1927	305	plaice	per 30	minutes	(9 stations,	Fig. 7).
July 1927	949	—	-	—	(15 —	— 8).
April 1928	200	—	-	—	(10 —	— 10).
June-July 1928	909	—	-	—	(14 —	— 11).

[1]) Five og the specimens caught in Thisted Broad had probably stayed there for a year or more and are omitted in this calculation.

[2]) In winter when the plaice lie partially buried in the bottom, the fraction of the stock which is caught in the area scoured is obviously smaller.

By taking into account the difference in area between Thisted-Visby Broads and Nissum Broad we find the size of the stock in Nissum Broad (x) to be:

April 1927 $x = \frac{148}{114} \cdot \frac{305}{15,5} \cdot 1.000.000 = 26$ million

July 1927 $x = \frac{148}{114} \cdot \frac{949}{15,5} \cdot 1.000.000 = 79$ million

April 1928 $x = \frac{148}{114} \cdot \frac{200}{15,5} \cdot 1.000.000 = 17$ million

June-July 1928 $x = \frac{148}{114} \cdot \frac{909}{15,5} \cdot 1.000.000 = 76$ million.

The calculations in respect to the size of the stock in Nissum Broad in April are based on fishing experiments carried out after the fish for transplantation had been captured. In April 1927 about 2.653.000 fish were removed for transplantation, in April 1928 nearly 3 million.

The great increase in the size of the stock from April till June-July can be explained in the following manner:

1) The great spring immigration from the North Sea into Nissum Broad has not come to an end when the transplantation (in April) is carried out.
2) As the fish grow during the months April-June, a migration of considerable proportions occurs from the shallows of less than 4 metres' depth in to the deeper water in the Broad.

In comparison with the plaice stock in Nissum Broad, the stock in the other parts of the Limfjord is numerically small. By the same method as that employed for ascertaining the size of the stock in Nissum Broad, we have calculated the size of the stock in the other parts of the Limfjord and have thereby obtained for example the following number of fish outside the 4 metre line in July 1928:

	Total Number	Number per hektare
Nissum Broad	76 million	5140
Lavbjerg Broad	10 —	2490
Kaas Broad	3,8 —	960
Venø Bay	5,2 —	870
Sallingsund and Vodstrup Broad	4,8 —	620

With respect to the above it must in addition be mentioned that, whilst in Nissum Broad a very large plaice stock is also present in shallower water than 4 metres, the stock within the 4 metre line in the other regions is extremely small.

The number of plaice planted in the different parts of the Limfjord in April 1928 was as follows:

	Total Number	Number per hektare
Thisted and Visby Broads	491.000	43
Livø Broad: central and eastern portions	658.000	51
Hannæs and Løgstør Broads	443.000	28
Risgaarde Broad, Louns Broad, and Hvalpsund	342.000	37

The average number of plaice planted during the years 1920—22 in the different parts of the Limfjord was as follows:

	Total Number	Number per hektare
Thisted and Visby Broads	353.000	31
Livø Broad: central and eastern portions	508.000	40
Hannæs and Løgstør Broads	342.000	22
Risgaarde and Louns Broads, and Hvalpsund	259.000	28

We are now in a position to investigate how great the yield is in relation to the density of the stock, and by taking into account the average annual yield in terms of value per hektare for the years 1920—22 we obtain the following result:

	No. of plaice per hektare	Yield in kroner per hektare
Nissum Broad	5140	0,9
Lavbjerg Broad	2490	7,0
Kaas Broad	960	28,0
Venø Bay	870	20,6
Sallingsund and Vodstrup Broad	620	ca. 20[1])
Thisted and Visby Broads	31	5,2
Risgaarde and Louns Broads, and Hvalpsund	28	1,6
Løgstør and Hannæs Broads	22	2,7

It is clear from the above that the yield of the fishery per unit area is greatest in the regions which are populated to a medium degree and least of all in the region which is most thickly populated, viz. Nissum Broad. There are many more plaice in this broad than is profitable. In spite of there being produced very much food suitable for plaice in Nissum Broad the yield here is very low. The stock here is so great that there is too little food for each individual fish. In Lavbjerg Broad also there are obviously more plaice than is advantageous. Kaas Broad, Venø Bay, and Sallingsund with the western portion of Livø Broad (Vodstrup Broad) have given the greatest yield per hektare.

Unfortunately there are no regions in the Limfjord where the density of the stock is between 100 and 500 fish per hektare and where the amount of the yield can be verified.

[1]) It has not been possible to calculate the yield accurately.

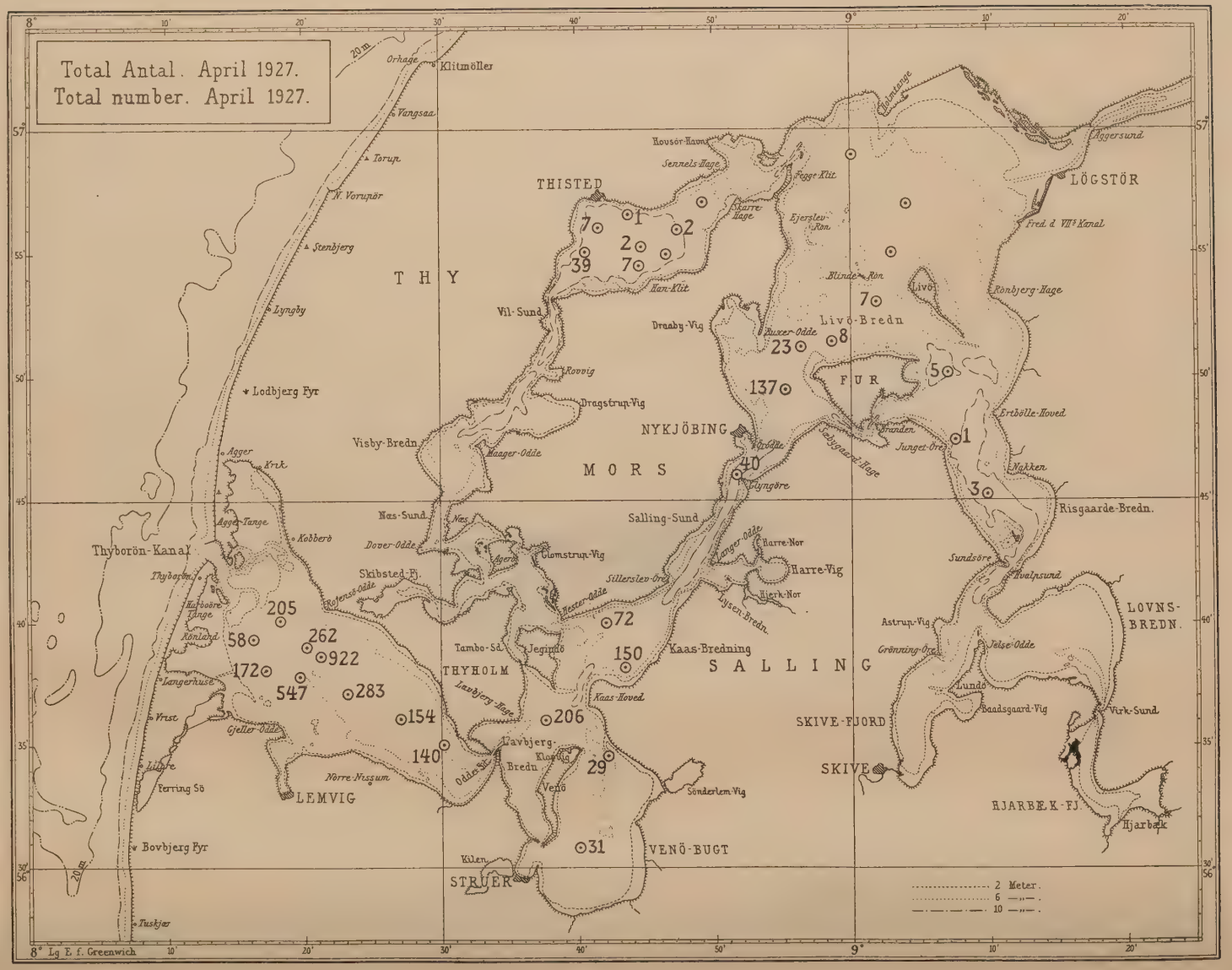

Fig. 7. Number of plaice caught per 30 minutes' haul with Eel-tog in April 1927. (At the stations without figures no plaice are caught).

Fig. 8. Number of plaice caught per 30 minutes' haul with Eel-tog in July 1927.

Total Antal. April 1928.
För Omplantningen.
Total Number. April 1928.
Before Transplantation.
THISTED
THY
LÖGSTÖR
Livø-Bredn
FUR
NYKJÖBING
MORS
SALLING
THYHOLM
LEMVIG
STRUER
SKIVE-FJORD
SKIVE
LOVNS-BREDN
RJARBÆK FJ
VENO-BUGT
Thyboron-Kanal
Kaas-Bredning
Harre-Vig
Salling-Sund
Nors-Sund
Visby-Bredn
Risgaarde-Bredn
Lodbjerg Fyr
Bovbjerg Fyr
Tuskjær
Ferring Sø
Nissum
Vil-Sund
Draaby-Vig
Dragstrup-Vig
Clomstrup Vig
Tambo-Sø
Jegindø
Kaas-Hoved
Sønderlem Vig
Venø
Bredn
Klovvig
Havbjerg
Lavbjerg Hage
Sennels Hage
Fegge Klit
Ejerslev-Ren
Blinde-Ren
Rønbjerg-Hage
Buxer-Odde
Ertbolle-Hoved
Nakken
Junget-Ore
Sundsøre
Tvalmsund
Astrup-Vig
Jelse-Odde
Lunde
Baadsgaard-Vig
Virk-Sund
Hjarbæk
Barre-Nor
Hjerk-Nor
Lysen Bredn
Sellerslev-Ore
Vester Odde
Dover Odde
Rolenso Odde
Agger-Tange
Kobbero
Thyborøn
Nørre Vorupør
Lyngby
Stenbjerg
Torup
Vangsaa
Klitmöller
Orhage
Aggersund
Fred. d. VII.s Kanal
Livø
Rønbjerg-Hage
Ertbolle-Hoved
Nakken
Risgaarde-Bredn
Sundsøre
Tvalmsund
Astrup-Vig
Jelse-Odde
Lunde
Baadsgaard-Vig
Virk-Sund
Hjarbæk
Barre-Nor
Harre-Vig

Fig. 10. Number of plaice caught per 30 minutes' haul with Eel-tog in April 1928. After transplantation.

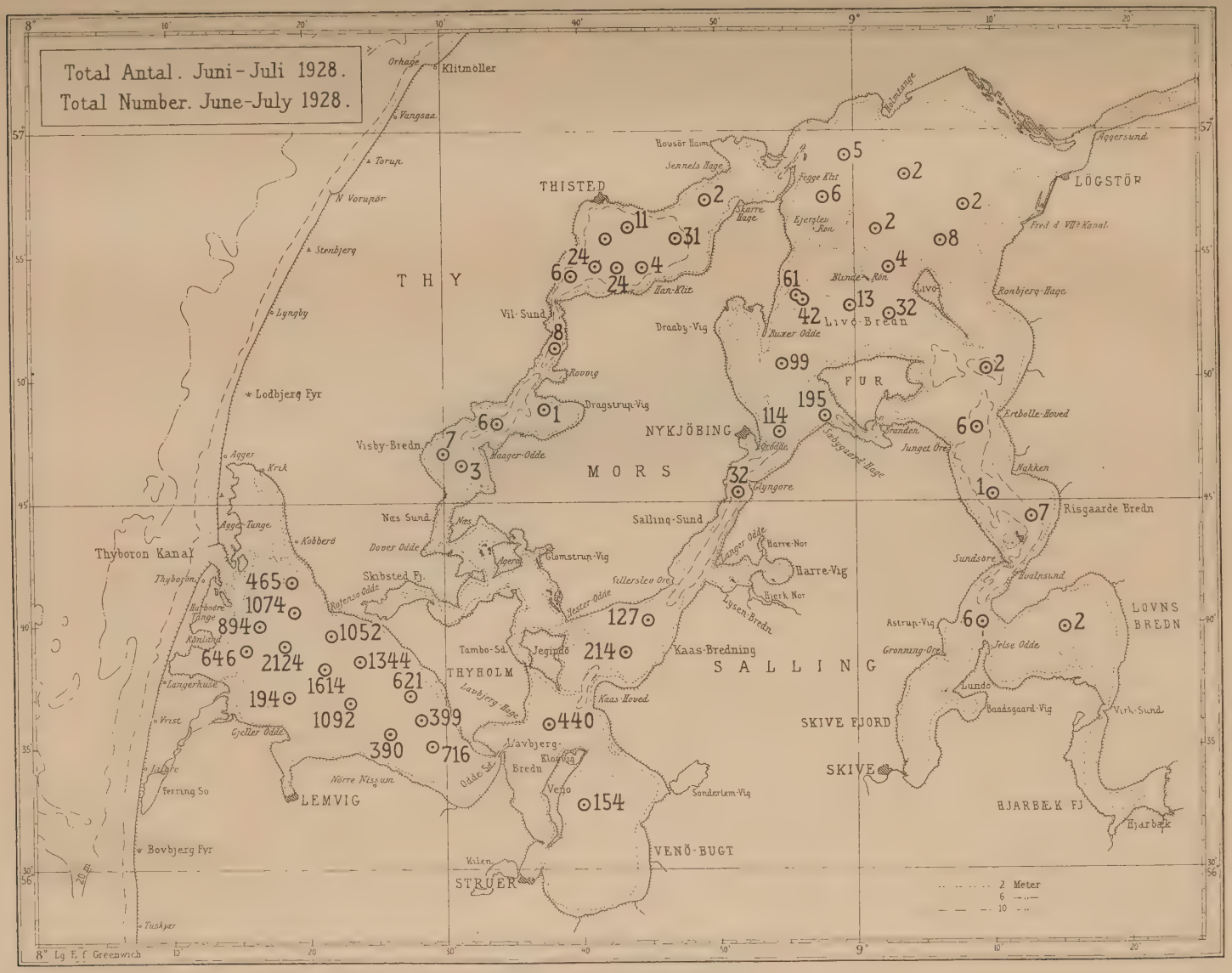

Fig. 11. Number of plaice caught per 30 minutes' haul with Eel-tog in June-July 1928.

It is clear that the stock of plaice in the areas planted is not as large as would be most advantageous. The areas where it is obviously most profitable to plant fish are Thisted and Visby Broads.

It should be mentioned that the average size of the plaice is least in the areas where the number of fish to the hektare is greatest and that in discussing the most profitable proportion of population to area the size of the fish is of very great importance.

7. Is the yield of the fishery in Nissum Broad diminished by plaice being taken from this broad for transplantation?

Several fishermen engaged in fishing in Nissum Broad maintain that the yield of the plaice fishery is less than normal for several months after the fish have been removed for transplantation, and they conclude from this that this removal damages the fishery in the Broad. We shall here attempt a closer investigation of this matter.

In Table 12 will be found figures taken from the Fiskeri-Beretning showing side by side the yield of the fishery in Nissum Broad during the years 1901—22 and the quantity of plaice removed for transplantation during the same period. If

Table 12. The yield of the plaice fishery in Nissum Broad, and the quantity of plaice removed for planting during the years 1902—1922.
(No information regarding the yield in recent years has been published).

	Yield		Quantity of plaice transplanted	
	Tons	100 Kroner	Tons	number of thousands
1901	25,8	56	c. 20[1])	c. 250[1])
1902	23,4	55	20	254
1903	22,0	48	27	338
1904	13,4	32	c. 25[1])	c. 300[1])
1905	13,3	39	24	295
1906	10,3	41	c. 25[1])	c. 300[1])
1907	13,3	51	c. 25[1])	c. 300[1])
1908	36,1	142	111	1.392
1909	20,5	82	128	1.600
1910	29,8	119	147	1.840
1911	26,4	105	146	1.821
1912	67,2	270	199	2.206
1913	173,4	481	188	2.216
1914	28,0	70	176	2.206
1915	23,4	98	176	2.206
1916	10,5	105	178	2.228
1917	25,9	130	0	0
1918	37,9	238	23	251
1919	92,2	645	116	1.456
1920	19,0	152	97	1.332
1921	47,0	182	95	1.315
1922	17,0	68	108	1.735

[1]) Estimated.

we calculate the correlation coefficient between the yield in tons and the number of fish removed for transplantation, we obtain $r = 0{,}40$ and $\sigma_r = 0{,}15$. The result of the calculation thus indicates that the removal of fish has had no injurious effect but has probably actually been of benefit.

It will be seen from the table that during the years 1901—07 when on an average about 0,3 million fish were taken from the Broad for transplantation the annual average yield of the fishery was only 17,4 tons. When the quantity of fish taken rose during the years 1908—11 to c. 1,4—1,8 million per year the average annual yield increased to c. 28 tons. When again during the years 1912—16 the quantity of fish taken rose to c. 2.2 millions per year the average annual yield increased further to c. 60 tons. In 1917, when no fish were taken from the Broad for transplantation, the yield fell to c. 26 tons. In 1918, when transplantation recommenced and c. 0,25 million fish were removed, the yield rose to c. 38 tons, and when the quantity of transported fish during the years 1919—22 reached c. 1,3—1,7 million per year, the annual average yield increased to c. 42 tons.

The fact that the yield of the fishery has undergone very marked fluctuations during periods when the quantity of fish removed for transplantation has been about the same (e. g. the periods 1912—16 and 1919—22) indicates however that the yield in the main is dependent on other factors than the amount of fish taken away for planting.

As mentioned in Chapter 6, we have been able, from the results of a series of comparative fishing experiments in Thisted and Visby Broads, and in Nissum Broad, to calculate approximately the size of the stock in the last-mentioned broad outside the 4 metre line, and have by this means arrived at the following results for June-July 1928:

Number of plaice in Nissum Broad outside the 4 metre line.

	April 1927	July 1927	April 1928	June—July 1928
Total number	26 million	79 million	17 million	76 million
Over 12 cm.[1])	19 —	51 —	13 —	55 —
— 15 cm.[1])	5,6 —	26 —	9,6 —	29 —
— 18 cm.[1])	2,9 —	4,9 —	3,3 —	10 —
— 20 cm.[1])	1,8 —	2,6 —	1,2 —	3,0 —
— 25 cm.[1])	0,2 —	0,2 —	0,2 —	0,3 —

There are in addition numerous young plaice in Nissum Broad at less depths than 4 metres. It has not yet been possible to calculate the number of these young fish, which mostly belong to the youngest and next youngest year classes, but it is probably greater in spring and early summer than the number outside the 4 metre line.

When we consider that the number of plaice caught annually as marketable

[1]) These calculations rest upon measurements of all plaice captured by fishing experiments from "Japetus Steenstrup" with Eel-tog in the named periods.

fish in the Limfjord only amounts to about 4 million, it becomes clear that the plaice stock in Nissum Broad is in comparison enormous. It has also been proved long ago and on numerous occasions by marking experiments and age determinations by means of otoliths that the plaice in Nissum Broad grow very slowly.

Nevertheless it is by no means improbable that the fishermen engaged in fishing in Nissum Broad have been able to notice a fall in the yield of the fishery for a short time after transplantation, since in fishing for fish to be transplanted proportionately more of the larger fish are caught than of the smaller. The comparatively small loss thus involved is however compensated for in other ways. Firstly a certain thinning out of the stock is brought about by capturing a million fish in certain spots and this undoubtedly will speedily result in the more rapid growth of the fish left behind in these spots. Secondly a number of the transplanted fish, when they have grown, will be caught in Nissum Broad on their migrating from the inner broads towards the North Sea. As has been shown by the marking experiments conducted by the Danish Biological Station, this emigration from Livø, Risgaarde and Louns Broads is on a large scale.

8. Can better results be obtained from the annual transplantations in the Limfjord without the expenditure being thereby increased?

a) It is clear from the previous chapters (3, 4, 5, 6) that it is more profitable to plant plaice in Thisted and Visby Broads than in Livø, Risgaarde, and Louns Broads. The planting for a long series of years of a larger number of plaice per hektare in the central and eastern portions of Livø Broad than in Thisted and Visby Broads has thus obviously been unprofitable. The planting of plaice in Hannæs and Løgstør Broads and in Risgaarde and Louns Broads, which they comparatively soon abandon, ought to be reduced to some extent in favour of planting in Thisted and Visby Broads. The experiments in 1912—16 showed that at least double as many plaice could with advantage be put out in Thisted and Visby Broads as has been the case in recent years.

If we assume that about Kr. 20.000 are available annually for the transplantation of plaice in the Limfjord, it must in accordance with the investigations be regarded as profitable to expend at least half this sum on planting plaice in Thisted and Visby Broads.

b) The marking experiments have shown that a very large percentage of the plaice planted in Livø, Hannæs, Løgstør, Risgaarde, and Louns Broads are recaptured in the western portion of Livø Broad ("Vodstrup Broad") and Sallingsund. The raising of the ordinary size limit from c. 25,7 cm. to c. 28,8 cm. (from 21,0 cm. to 23,5 cm. to the base of the caudal fin), which by enactment of the Ministry of Agriculture has been in force for a number of years in respect to the above-mentioned broads to the east of a line from Jørsby Church to the western brush-buoy on Holme-

flak and further to Rødsteen on Fur, should be put into operation also for the western portion of Livø Broad and Sallingsund.

c) Since it has been found that a very large percentage of the planted fish has been destroyed by fishing operations before reaching a marketable size, it would undoubtedly be profitable to forbid the use of gill nets in the planted areas and in the western portion of Livø Broad for the first few months after planting for instance up till the end of July.

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V.

The Relation between the Size of the Plaice Stock and the Quantity of "First Class Plaice-Food" in certain Parts of the Limfjord.

By

AAGE J. C. JENSEN

An investigation of the relation between the fluctuations from year to year in the size of the plaice stock and in the quantity of food is possible for certain areas in the Limfjord, seeing that valuations have been carried out here on the initiative of C. G. Joh. Petersen year after year since 1910. We possess at the same time fairly good information as to the size of the plaice stock in one of these areas, viz. in Thisted-Visby Broads. It is here determined practically solely by the extent of the transplantations of fish to this area, only a slight immigration of plaice occurring from the other parts of the Limfjord and also only a slight emigration from the area. Valuations have been carried out very regularly in Thisted Broad, and bottom samples taken more closely together than in the other Limfjord areas (cp. H. Blegvad, No. III in this Report). In several of the other areas, to which plaice are transplanted, the quantity of the transplanted fish has only a slight effect on the size of the stock, as the latter is determined chiefly by the natural immigration which takes place in the spring and early summer. In the case of Thisted-Visby Broads, A. C. Johansen has proved that the size of the catch is determined to a very considerable extent by the transplantations, that is to say, by the size of the stock in the spring[1]). In the areas grouped by the Danish Fishery Statistics under the heading of District B, i. e. Sallingsund, Livø Broad, Risgaarde and Louns Broads, and Skive Fjord, the aggregate catch of which is published in the Danish Fiskeri-Beretning, the amount of the catch is also to some extent determined by the size of the stock in the spring and early summer. In this district that part of the stock from which the fishery is maintained is in general, on account of the emigrations from this area, smaller than the stock present after the immigration and the transplantation in spring and early summer.

In Nissum Broad, Lavbjerg and Kaas Broads, and Venø Bay, where the stock consists principally of undersized fish, the fluctuations in the size of the stock are only little known, and for this reason alone an investigation of the relation between the size of the stock and the quantity of plaice-food cannot be carried out for these areas.

In the following we shall therefore confine ourselves to the study of the conditions prevailing in Thisted Broad and District B.

[1]) A. C. Johansen: "The extent of the annual transplantations in the Limfjord and the yield resulting therefrom", No. IV in this Report.

The following four points will be subjected to an investigation based on the material available:

1) The variation in the quantity of food, as determined by valuations, in the course of the year within each of the two areas.
2) The relation between the quantity of food, as determined by valuations, present in the two areas.
3) Whether the quantity of food, as determined by valuations, has any effect on the size of the catch.
4) Whether the quantity of food, as determined by valuations, is influenced by the size of the plaice stock.

It is moreover of interest in this connection to investigate whether the quantity of certain other species of fish (*Zoarces viviparus* and *Gobius niger*) has any demonstrable effect on the quantity of "first class plaice-food", as determined by valuations, and finally whether the temperature of the water in the summer and autumn months has any effect on the size of the catch; the temperature of the water must namely be assumed at the outset to be one of the factors influencing the upgrowth of the bottom invertebrates which constitute the most important plaice-food.

1) Values representing the quantity of "first class plaice-food" in the Limfjord are given in tabular form by P. Boysen-Jensen[1]) and H. Blegvad[2]). The valuations in the Limfjord extend from April till October, the majority being carried out in April—May and September—October.

If we calculate the mean values for the quantity of food per square metre in Thisted Broad during the different months we obtain:

Table 1. Average quantity of "first class plaice-food" in Thisted Broad in grams per square metre, 1910—1927.

	April	May	June	July	Aug.	Sept.	Oct.	Mean of all years
Mean (g. per sq. m.)	29,7	43,6	76,2	32,5	44,2	34,0	69,2	42,6
No. of years	*5*	*10*	*2*	*2*	*2*	*13*	*4*	*18*
Mean (g. per sq. m.)		39,0				42,3		
No. of years		*15*				*17*		

It will be seen that the quantity of "first class plaice-food" in Thisted Broad is on an average the same in each of these months. From spring till autumn neither increase nor decrease is perceptible in the average quantity of food. If we compare the quantity of "first class plaice-food" solely in the years for which we possess

[1]) P. Boysen-Jensen: Valuation of the Limfjord. I. Report Danish Biol. Stat. XXVI (1919) 1920.

[2]) H. Blegvad: No. III in this Report Table 1.

data from valuations made both in April—May and Sept.—Oct. (15 years in all) we obtain an average of 39,0 g. per sq. metre for April—May and 41,9 g. per sq. metre for Sept.—Oct., i. e. very nearly the same quantity.

As shown by the tables published by P. Boysen-Jensen and H. Blegvad, the quantity of food ascertained by the different valuations varies however to some extent.

By calculating the correlation between the quantity of "first class plaice-food" in the spring (April—May) and autumn (Sept.—Oct.) we arrive at the following:

Correlation coefficient between the quantity of "first class plaice-food" in Thisted Broad:

Spring and autumn of the same year.... $r = 0{,}14$; $\sigma_r = 0{,}25$
Autumn and spring of following year.... $r = 0{,}93$; $\sigma_r = 0{,}04$

the calculations being for 15 and 13 years respectively.

It will be seen that the quantity of food in the main remains unaltered from autumn to spring[1]), whilst during the months June—August it increases in some years and decreases in others. In Fig. 1 the quantity of food in one autumn is compared with that in the following spring.

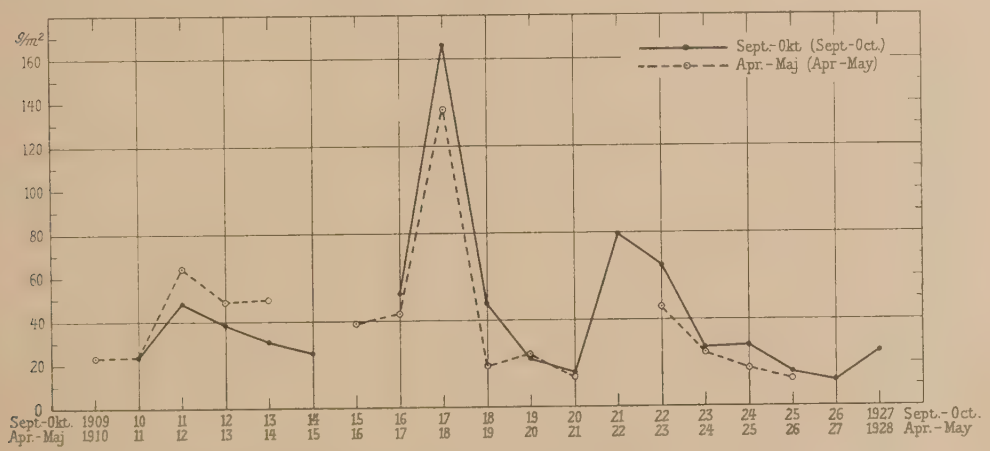

Fig. 1. Quantity of "first class plaice-food" autumn and following spring in Thisted Broad.

By calculating the means for the different months we obtain the following values for the quantity of food in District B[2]);

[1]) In the following the mean value for the quantity of food in one autumn and the following spring is termed the quantity of food in winter.

[2]) Calculated from the values published by P. Boysen-Jensen, 1919, and H. Blegvad, 1928, the different areas of the regions in question being taken into account.

Table 2. Average quantity of "first class plaice-food" in District B in grams per square metre, 1910—1927.

	April	May	June	July	Aug.	Sept.	Oct.	Mean of all years
Mean (g. per sq. m.)	11,4	24,9	40,0	23,0	38,4	42,0	87,0	40,7
No. of years	*2*	*8*	*2*	*4*	*2*	*11*	*2*	*14*
Mean (g. per sq. m.)		22,2				49,0		
No. of years		*10*				*13*		

It will be seen that in District B there is a decided increase in the quantity of "first class plaice-food" from April—May till Sept.—Oct. If we calculate the average quantity solely in the years for which we possess data from valuations made

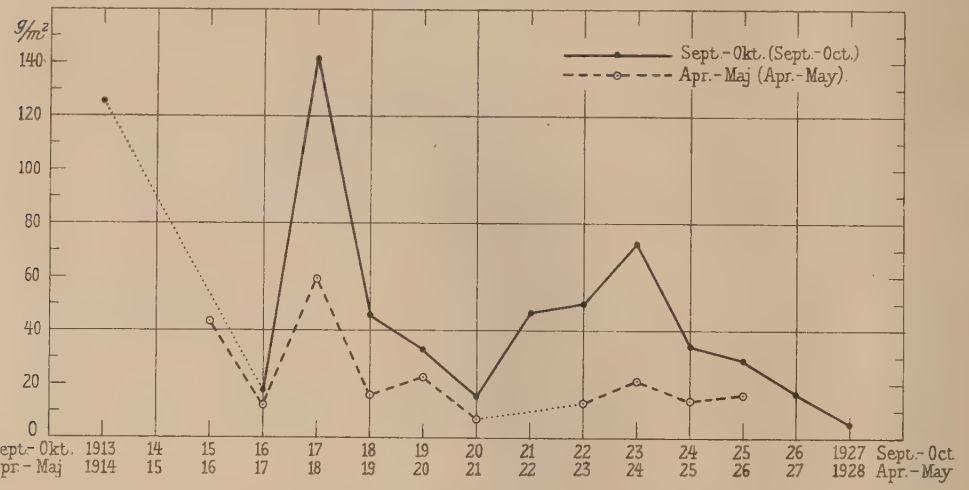

Fig. 2. Quantity of "first class plaice-food" autumn and following spring in District B.

both in April—May and Sept.—Oct. (10 years) we obtain 22,2 g. per sq. metre as the mean for April—May and 45,5 for Sept.—Oct. The quantity is on an average double as great in the autumn as in the spring. It will further be seen that the quantity of food per sq. metre is on an average about the same as in Thisted Broad in the autumn but only half as great in the spring.

By calculating the correlation between the quantity of plaice-food in the spring (April—May) and the autumn (Sept.—Oct.) we obtain:

Correlation coefficient between the quantity of "first class plaice-food" in District B:—

Spring and autumn of the same year ... $r = -0,26$; $\sigma_r = 0,29$
Autumn and spring of following year.... $r = 0,93$; $\sigma_r = 0,05$

the calculations being for ten years in each case.

The variations (decrease) in the quantity of food from autumn to the following spring in District B thus occur with some degree of uniformity year after year. Also

in this locality the period from spring till autumn is a time when in certain years the quantity of food is reduced and in others augmented.

The quantity of "first class plaice-food" in the autumn (Sept.—Oct.) and spring (April—May) in District B is shown in Fig. 2.

The perishing of the food animals on account of the low temperature in the winter time cannot affect to any great extent the variations in the quantity of plaice-food from year to year, seeing that if the reduction in the quantity of food from autumn to the following spring were due to this cause it would vary considerably from year to year, which is not the case.

This decrease in the quantity of "first class plaice-food" which takes place between Sept.—Oct. and April—May is more probably to be accounted for by the fact that the bottom invertebrates in question are devoured in the course of the winter. As regards Nissum Broad, P. Boysen-Jensen has pointed out that the 0-group of these food animals disappears to a great extent in the course of the first winter, evidently through their being devoured[1]).

2) If we now take the mean of the quantity of "first class plaice-food" in autumn (Sept.—Oct.) and the following spring (April—May) for Thisted Broad and compare it with the corresponding mean for District B[2]), we obtain the correlation coefficient between the quantity of food in the two regions, $r = 0{,}64$; $\sigma_r = 0{,}16$.

The variations in the quantity of "first class plaice-food" is thus (as is also evident from Blegvad ibid. Fig. 1, p. 44) in a marked degree the same in these two regions in the Limfjord. This indicates that the quantity of plaice-food is determined mainly by factors which are equally potent in both regions. The plaice stock in the two regions is not such a factor, since that in Thisted-Visby Broads is practically entirely determined by the extent of the transplantations to these regions, whereas in District B on the other hand it is principally determined by the natural immigration.

3) If we compare the catch in Thisted-Visby Broads, which may be taken as an expression for the size of the stock in autumn, with the quantity of "first class plaice-food" in Thisted Broad in April—May we obtain $r = 0{,}04$; $\sigma_r = 0{,}26$, and if we compare it with the quantity of food in Sept.—Oct., $r = -0{,}25$; $\sigma_r = 0{,}25$ (the calculations being for 15 and 17 years respectively).

It will be seen that the yield by weight of the plaice fishery cannot be shown to be dependent on the quantity of "first class plaice-food", as determined by valuations.

Since the yield by weight of the plaice fishery in Thisted-Visby Broads is dependent to a considerable extent, as mentioned above, on the extent of the transplantation to this region, it is possible that this dependence is so overwhelming that a less pronounced dependence on the quantity of food is thereby concealed.

We will therefore investigate whether the quantity of food is a determining

[1]) P. Boysen-Jensen: Rep. Dan. Biol. Stat. XXVI (1919) 1920. p. 26.

[2]) In the cases where we only possess data from valuations undertaken either in autumn or spring, it is calculated for District B that the quantity of food in spring is half that in autumn.

factor for the discrepancies between the number of plaice produced in a given year by the area and the number which might have been expected from the extent of the transplantations of plaice. We possess a means of judging this in the production of plaice in the area per ton of fish transplanted.

By calculating the correlation coefficient between the production per ton of transplanted fish and the quantity of "first class plaice-food" prior to and simultaneously with the presence of the plaice stock in question, we obtain:

Production per ton of transplanted fish correlated with the quantity of food.

1) with the quantity of food in the previous winter .. $r = 0{,}11$; $\sigma_r = 0{,}23$
2) with the quantity of food in the following winter .. $r = -0{,}04$; $\sigma_r = 0{,}23$

the calculations being for 18 years in both cases.

It will be seen that the quantity of food, as determined by valuation, has no appreciable effect on the amount produced by the area per ton of transplanted fish.

One main reason for the production of plaice not appearing to depend at all on the quantity of food is probably the fact that the quantity of food, as determined by valuation, is only a poor expression for that which has been accessible to the plaice throughout the summer. The latter is namely determined by the amount of food still remaining from the previous year, by the production during the summer, and by the amount of food devoured by the other consumers, viviparous blenny (*Zoarces viviparus*), black goby (*Gobius niger*), nassa (*Nassa reticulata*), starfish (*Asterias rubens*), etc., and the valuations only give the momentary result of all the contributing factors.

In the case of District B, as mentioned on page 89, we have no other gauge for the size of the stock than the catch, except in recent years when quantitative fishing experiments with Eel-tog have been carried out for this very purpose of determining the size of the stock[1]).

By calculating the correlation coefficient between the catch in District B and the quantity of food in this area in the spring (April—May) of the same year we obtain $r = -0{,}25$; $\sigma_r = 0{,}30$ (the calculations being for 10 years), and by calculating the corresponding coefficient for the autumn of the same year we obtain $r = 0{,}54$; $\sigma_r = 0{,}20$ (13 years). It will be seen that no connection can be perceived between the quantity of food in spring and the size of the catch. Yet the latter correlation coefficient indicates that the increase in the quantity of food in the course of the summer has a stimulating effect on the yield of the plaice fishery in the area; in other words that when the upgrowth of "first class plaice-food" throughout the summer is great a more extensive immigration takes place into the area or a less extensive emigration outwards than when it is small. If there exists such a connection between the upgrowth of first class food and the migrations of plaice we must expect a greater

[1]) A. C. Johansen, No. IV in this Report.

correlation between the quantity of food and the natural stock in District B (i. e. the stock considered as apart from the effect of the transplantations to the area). Fortunately the effect of the transplantations on the catch in District B can be eliminated statistically, i. e. after calculating the regression coefficient from the anomalies for transplantation and catch; the anomalies for the size of the natural stock in the area can thereby be found. By calculating the correlation between these values for the natural stock and the quantity of "first class plaice food" in April—May of the same year, we obtain the correlation coefficient $r = -0{,}09$; $\sigma_r = 0{,}31$ (the calculations being for 13 years), and in (Sept.—Oct. of the same year $r = 0{,}63$; $\sigma_r = 0{,}17$ (13 years). In the latter case we thus find a positive correlation coefficient which is more than three times as great as σ_r, i. e. the connection between the size of the natural stock and the quantity of food in Sept.—Oct. may be taken as really existing, and the calculation shows that a large quantity of food in autumn is present when the natural stock is large, and a small quantity when the natural stock is small. The correlation coefficient is however too uncertain, in view of the fairly short series of years covered by the observations, for the observations of the quantity of food to have any practical value as a means of predicting the yield of the fishery.

4) In the case of Thisted-Visby Broads, the size of the plaice stock in spring, after the transplantation has been carried out, is principally determined by the extent of the transplantation, although in spring a certain number of plaice remain from the transplantation of the previous year so that part of the effect of a transplantation in one year is not perceptible in the catch until the following year, about one quarter on an average according to A. C. Johansen[1]). Since natural mortality reduces the number of transplanted plaice most greatly shortly after transplantation, the plaice which have just been transplanted in spring undoubtedly predominate, especially in numbers, over the plaice transplanted in the previous year to a greater extent than later in the year. The sum of three quarters of the plaice transplanted in any given year and one quarter of those transplanted in the following year may however be taken also in spring to be a better expression for the size of the stock than the numbers transplanted in that year alone.

If by calculating the correlation we investigate the effect produced by the extent of the transplantations on the quantity of food, as determined by valuations, we obtain, when the transplantation to Thisted-Visby Broads ($^3/_4$ in one year and $^1/_4$ in the next) is correlated with the amount of "first class plaice-food" in Sept.—Oct., $r = -0{,}33$; $\sigma_r = 0{,}22$ (observations extending over 17 years). As only about one quarter of the effect of the transplantation in any given year derives from the previous year, it is reasonable to expect that the effect of the transplantation on the quantity of food in the spring in question is very slight, and by calculating the correlation between the extent of the transplantation and the quantity of food in

[1]) A. C. Johansen, No. IV, p. 65 in this Report.

April—May we find the correlation coefficient $r = -0{,}05$; $\sigma_r = 0{,}21$ (observations extending over 15 years).

These calculations show that the effect of the size of the plaice stock on the quantity of food in Thisted Broad is in any case very slight. Possibly the negative correlation coefficient between the extent of the transplantation and the quantity of food in the autumn is a sign of a small effect produced by the size of the stock, in that a large plaice stock reduces the quantity of food more rapidly than a small one. The fact that there was a similarly small negative correlation between the size of the catch (which is an expression for the size of the stock in autumn) and the quantity of food in Sept.—Oct. points in the same direction.

As the quantity of food, as determined by valuations, only showed a slight tendency to depend on the size of the plaice stock in the locality, it is of interest to investigate the question as to whether the fish which consume "first class plaice-food" have altogether any great influence on the quantity of first class food, as determined by valuations.

That the presence of a great quantity of food during the period from the autumn of 1917 till the spring of 1918 cannot be ascribed to very few or no plaice being transplanted in these years is clear from the fact that this maximum was even greater in Sallingsund, where the transplantations in any case have a very slight effect on the number of plaice, than in Thisted Broad, where the transplantations have a great effect on the size of the plaice stock. As regards the other fish which in the Limfjord are large consumers of this food, viz. the viviparous blenny and the black goby, H. Blegvad has published in this Report, No. III, Table 2, p. 48, the following information as to their numbers in the Limfjord during the period 1908—27.

Frequency of Zoarces viviparus and of Gobius niger found in the Limfjord by fishing experiments with Eel-tog, according to H. Blegvad.

Year	Number of fishing experiments (hauls with Eel-tog)	Number of Zoarces viviparus caught per 10 Min. with Eel-tog	Frequency of Gobius niger	Year	Number of fishing experiments (hauls with Eel-tog)	Number of Zoarces viviparus caught per 10 Min. with Eel-tog	Frequency of Gobius niger
1908	26	0.9	None found	1918	42	15.5	A few at all places
1909	59	4.7	do.	1919	24	3.4	None found
1910	87	3.0	do.	1920	35	1.9	do.
1911	26	0.1	do.	1921	54	2.2	do.
1912	8	0.0	A few in Nissum Br.	1922	33	3.2	do.
			A few in Nissum and	1923	48	5.9	do.
1913	16	1.2	Thisted Br. and in Sallingsund	1924	31	12.7	do.
1914	4	0.3	A few found	1925	43	19.8	A few in the autumn
1915	5	3.8	Some found	1926	72	20.7	Many at all places
1916	13	8.4	Many at all places	1927	83	26.4	In quantities at all places
1917	10	20.5	do.				

That the great numbers of *Zoarces* and *Gobius niger* do not constitute the main-factors, which have kept down the quantity of "first class plaice-food" at a minimum during the years subsequent to 1923 is evident from the fact that the frequency of *Zoarces* and *Gobius niger* during the very years when the quantity of "first class plaice-food" reached its maximum, 1917—18, appears to be the same as in the years following 1923 (cp. Table above).

The number of fish consuming this food thus seems to be of very little importance as a factor affecting the quantity of "first class plaice-food", as determined by valuations.

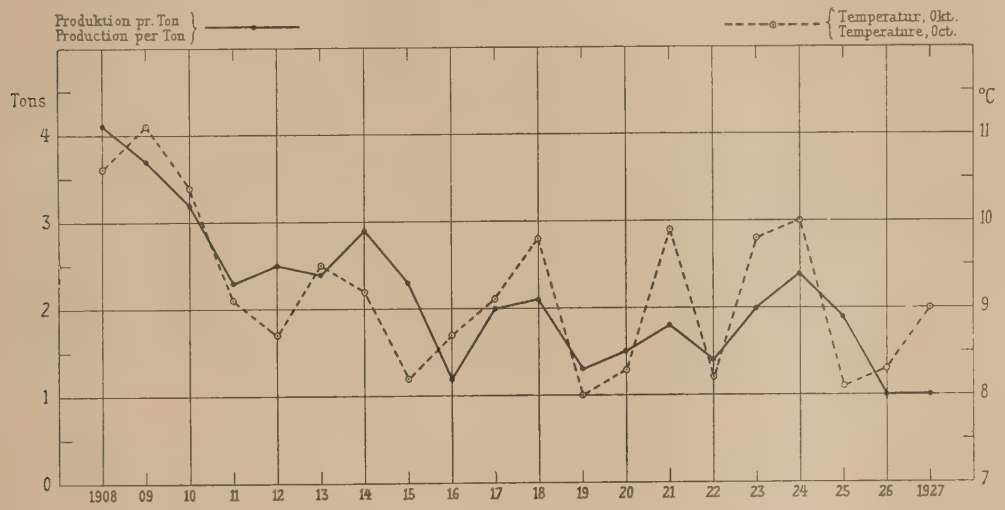

Fig. 3. Comparison between yield of the plaice-fishery in Thisted-Visby Broads per ton of plaice transplanted to this region and the surface-temperature at Oddesund in October.

Finally it is of interest to investigate the question as to whether the temperature of the water in the summer and the autumn months has any influence on the size of the catch, since it must be one of the factors influencing the upgrowth of the animals on which plaice feed.

Unfortunately we possess no regular records of the temperature in the deeper layers of the Limfjord, but only of the surface temperature at Oddesund and Aalborg.

By correlating the production of plaice per ton of transplanted fish in Thisted-Visby Broads during the period 1908—27, when it was fairly uniform[1]), with the temperature (taken at the surface at Oddesund in August—November) we obtain the following values for the coefficient:—

Production per ton of transplanted plaice correlated with the temperature in different months.

1) in August ..... $r = 0{,}05$; $\sigma_r = 0{,}22$
2) in September ... $r = 0{,}15$; $\sigma_r = 0{,}22$

[1]) A. C. Johansen, ibid. p. 65

3) in October..... $r = 0{,}75$; $\sigma_r = 0{,}09$
4) in November.... $r = 0{,}13$; $\sigma_r = 0{,}22$.

It will thus be seen that there is a certain and positive correlation between the production of plaice per ton of transplanted plaice and the temperature in October.

That no certain correlation can be perceived between the production per ton of transplanted plaice and the temperature in August and September may be due to the surface temperature in summer being a poor expression for the temperature in the deeper water layers since the latter is largely dependent on the degree to which the water layers are mixed[1]). The connection between the production per ton of transplanted fish and the temperature in October is shown in Fig. 3.

Correspondingly one would expect to find in District B a positive correlation between the size of the natural stock of plaice and the temperature in October.

By calculating the correlation between the catch of plaice in District B and the surface temperature at Oddesund in October we obtain $r = -0{,}31$; $\sigma_r = 0{,}20$ (1908—27). The effect of the transplantation can however as already mentioned be eliminated and by calculating the correlation coefficient between the catch in District B, after eliminating the effect of the transplantations to the area, and the temperature in October we obtain $r = 0{,}51$; $\sigma_r = 0{,}17$ (the calculations being for the years 1908—27); that there exists a positive correlation may accordingly be considered as trustworthy. The catch in District B thus proves as in the case of Thisted Broad to be dependent on the temperature of the water.

[1]) Aage J. C. Jensen: "Remarks on the Hydrography of the Limfjord", in this Report No. II.

VI.

The Haddock in the Belt Sea and the Western Baltic during the Years 1926—28.

By

ERIK M. POULSEN

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1. Introduction.

A. C. Johansen has discussed in a paper in the Journal du Conseil[1]) the unusually large quantities of haddock which occurred in the Belt Sea in the winter of 1925—26 and the causes thereof. In the Belt Sea (see Table 1), where normally

Table 1. Yield of the Danish haddock-fishery in the Belt Sea in kilogrammes in the years 1909—1928 as noted in the Danish Fiskeri-Beretning.

Year	Kg.	Year	Kg.	Year	Kg.
1909	0	1916	5.100	1923	200
1910	0	1917	0	1924	270
1911	250	1918	0	1925	59.000
1912	0	1919	0	1926	740.000
1913	15.550	1920	0	1927	c. 80.000
1914	2.700	1921	0	1928 (only the first three months of the year)	c. 80.000
1915	0	1922	0		

either no haddock at all are caught or are only caught in quantities varying from a few hundred to two or three thousand kilograms (in a certain year however amounting to 15.000 kg.), there were caught in the first 2 months of 1926 over 500.000 kg. Dr. A. C. Johansen showed that this great fishery yield was caused by the haddock larvae having been carried into these waters in large quantities in the spring of 1923 by a strong inflow of salt water and by their having remained there and grown into marketable haddock in the winter of 1925—26. The bulk of these haddock attained sexual maturity in the spring of 1926, and of these the ones that escaped capture emigrated. Analyses from the spring of 1926 showed that about 10 per cent. of the haddock did not become mature during this year, and Dr. Johansen was of the opinion that these haddock would remain in the Belt Sea until they became sexually mature — i. e. probably one year more. There would thus in the winter of 1926—27 still be a fairly considerable stock of haddock which would justify fishing operations.

[1]) A. C. Johansen: On the Remarkable Quantities of Haddock in the Belt-Sea during the Winter of 1925—26, and Causes leading to the same: Journal du Conseil International pour l'Exploration de la mer. Vol. 1 No. 2. 1926.

2. The haddock fishery in the Belt Sea during the winters of 1926—27 and 1927—28.

A. The winter of 1926—27.

The unusually large catches of haddock in the Belt Sea in the winter of 1925—26 came to an end in the course of March.

During the following spring months and throughout the summer of 1926 no trace of haddock was to be found in the Belt Sea; in August however a few haddock about 60 cm. in length were caught with bait in deeper water in Aabenraa Fjord, and in the Great Belt a few haddock of the same size were caught with the otter seine.

Towards the autumn, haddock were found again more generally in the fishing nets. In the last half of September a few haddock were thus caught with the Danish seine in the southern part of Little Belt to the south of Stenderup-Hage. In October a number of fairly good catches were made with the Danish seine in the southern part of the Kattegat at the entrance to Øresund. Throughout the whole of Little Belt catches were made amounting to c. 150 kg. per day. It is of particular interest that during these fishing operations a number of young haddock were caught of about 10—15 cm. in length — i. e. hatched in the spring of 1926. In October an attempt was made to fish for haddock by a number of cutters from Esbjerg, but the catches were too small for the fishing to be remunerative, and the cutters accordingly ceased operations. In November also the haddock fishery in the Belt Sea was of no great importance; in the waters of South Jutland a catch was made with the purse seine on one occasion of about 100 kg. The best yield was obtained in the south-eastern Kattegat at the entrance to the Sound. In December the yield was a little larger. 9 cutters from Esbjerg together captured about 5000 kg. in this month in the waters of South Jutland. The best fishing occurred in Aabenraa Fjord, where in some hauls about 150 kg. were taken. At Vejsnæs Flak between Als and Ærø fishing was carried on with the otter seine, and daily catches were made of 75—100 kg.

In the southern part of Langeland Belt haddock were caught on hooks, and as a rule there were more haddock than cod on the hooks. The largest yield was obtained in the northern part of the Great Belt, up to 200 kg. per day being caught with the otter seine.

In January 1927 fishing improved to some extent even though it was still rather unsatisfactory for the cutters which had come from other parts to the Belt Sea with the intention of catching haddock. In this month about 100 cutters, mainly from Esbjerg, took part in the fishing. In January about 20.000 kg. were landed at Aabenraa and about 10.000 kg. at Sønderborg. Smaller catches were made in the Great Belt to the east of Romsø.

In February the fishery began to decrease. 12.000 kg. were landed in Aabenraa and Sønderborg together. At the beginning of the month fishing was carried on by 16 cutters, but towards the end of the month only 6 cutters made the attempt. In Aabenraa Fjord and outside it the haddock had by now almost completely dis-

appeared. Fishing was now carried on farther to the east in the deep basin between Als and Ærø. In the northern part of Great Belt only quite a few haddock were caught.

The price of haddock in December was 30—60 Øre per kg.; in January about 50 Øre and in February 60—80 Øre per kg.

KATTEGAT
JYLLAND
FYEN
STORE BÆLT
SJÆLLAND
LILLE BÆLT
Aarhus
Samsö
Odense
Kalundb.
Holbæk
Roskilde
København
Malmö
Helsingör
Helsingborg
Kullen
Hesselö
Gilleleje
Isefjord
Nyk.
Sejrö
Kallundb.
Korsör
Nyb
Nakskov Rev
Nakskov
Laaland
Falster
Langeland
Langelandsbælt
Faxe
Stevns
Falsterbo
Moen
KRIEGERS FLAK
Flensborg
Als Sund
Als
Aabenraa Fjord
Slimmde
Eckernförde
Kiel
Neustadt
Neustädter Bugt
Buk
Warnemünde
Rostock
Travemünde
Lübeck
Elben
Femern
Gedser
Darsserort
Rügen
Stralsund
Hesteholved
Skjoge
Tärnor
Hadersleben
Aassens
Svendb
Faab
Bog
Middelf
Kjerteminde
Kolding
Fredericia
Vejle
Horsens
Grenaa
Fornæs
Gilleleje
Helsingör
Nyk.
Sejrö
Kallundb.
Holbæk
Roskilde
Korsör
Nyb
Nakskov Rev
Nakskov
Faxe
Stevns
Falsterbo
Tärnor
Skjoge
Moen
KRIEGERS FLAK
Falster
Hestehoved
Gedser
Darsserort
Rügen
Stralsund
Warnemünde
Rostock
Femern
Eckernförde
Kiel
Neustadt
Neustädter Bugt
Buk
Travemünde
Lübeck
Elben
Flensborg
Slimmde
Als Sund
Als
Aabenraa Fjord
Svendb
Faab
Bog
Middelf
Kjerteminde
Kolding
Fredericia
Vejle
Horsens
Aarhus
Grenaa
Fornæs
Gilleleje
Hesselö
Helsingör
Helsingborg
Kullen
Isefjord
Samsö
Odense
Aassens
Hadersleben
Nakskov
Laaland
Falster
Langeland
Langelandsbælt
Faxe
Stevns
Falsterbo
Tärnor
Skjoge
Moen
KRIEGERS FLAK

a number of haddock were caught weighing 2—3 lbs. each to the south-west of Fehmern Belt lightship. Similarly in November some haddock were caught in the Western Baltic, a few specimens being over 50 cm. in length, one being as much as 61 cm. In December fishing was still poor. In January 1927 haddock were caught in Eckernförde Bay and in Neustädter Bay, the amount caught in January in the latter locality being 250 kg. in all. In addition haddock were caught in Kiel Bay throughout the whole winter. The most easterly locality in the Baltic where haddock were caught was Swinemünde Bay. In the beginning of March the German haddock fishery ceased rather suddenly.

Fishing for haddock in the Belt Sea and the western Baltic in the winter of 1926—27 was thus poor in comparison with the winter of 1925—26, but on the other hand extremely large compared with the normal yield. The yield of the Danish haddock fishery in the Belt Sea and Baltic in the winter of 1926—27 was about 80.000 kg. — i. e. rather more than one tenth of the yield in the winter of 1925—26 (c. 700.000 kg.). As mentioned above, Dr. Johansen found that about 10 per cent. of the haddock did not become sexually mature in the spring of 1926, and expressed the opinion that this tenth would remain in the Belt Sea for one more year. The fact that the yield in the winter of 1926—27 was about one tenth of that in 1925—26 confirms this hypothesis, and the analyses which were made in the spring of 1927 of the haddock stock in the Belt Sea show, as will be clear from the following, that the haddock which were caught in 1927 also for the most part belonged to the 1923 year class.

B. The winter of 1927—28.

There was no fishing for haddock in the Belt Sea throughout the summer of 1927, except that on one occasion 100 kg. were caught in one haul in the Great Belt off Halskov Rev. Haddock were thus present in the Belt Sea even in the summer months.

Not until November did haddock appear again in the fishing nets. Some catches of about 80 kg. were made during this month in the southern part of Langeland Belt; haddock were also captured in the waters east of South Jutland in November but only in small quantities. The bulk of the marketable fish were about 50 cm. in length, but a number of young fish were also found, about 15—18 cm. in length.

In December about 25 cutters were engaged in fishing in the waters of South Jutland, capturing on an average about 15 kg. of haddock per haul. On exceptional occasions 200 kg. were caught in one day. Also during these fishing operations there were observed a number of young fish about 15 cm. in length.

In January 1928 the catches were still small; the total yield of the haddock fishery in the waters of South Jutland, which was now being carried on by some fifty vessels, was about 35.000 kg. Haddock were also caught in the Great Belt and Langeland Belt up to 500 kg. being landed per day in Kerteminde.

In February the fishery greatly decreased. In this month the yield in the waters

of South Jutland was about 6000 kg. Similarly in the other parts of the Belt Sea the fishing was poor.

In March the yield of the haddock fishery both in the Belt Sea area and in the Western Baltic was extremely poor.

The yield of the haddock fishery in the Belt Sea and the Western Baltic in the winter of 1927—28 was in all probability approximately 80.000 kg., of which by far the greatest part was obtained in January. Just as in the two previous winters, the 1923 year class was also during this winter completely predominant in the catches, but it is of particular interest that during this winter a number of small haddock were observed of the 1927 year class. (The age composition of the stock will be discussed in a later section.)

3. The age composition of the stock of haddock in the Belt Sea during the winters of 1926—27 and 1927—28.

A. The winter of 1926—27.

In the course of January, February, and of March 1927 a number of analyses were made of haddock from the Belt Sea.

These analyses (Tables 2 and 3) show that the stock in the spring of 1927, as in the spring of 1926, consisted predominantly of fish of the 1923 year class. Of 278 fish subjected to age determination 221, i. e. 79 per cent., belonged to the 1923 year class. The distribution according to age was as follows:

Year class.....	1926	1925	1924	1923	1922	1921	Total
No. of fish	1	32	8	221	15	1	278

In the winter of 1925—26 the distribution was somewhat different:

Year class	1925	1924	1923	1922	1921	Total
No. of fish	1	0	301	2	1	305

The predominance of the 1923 year class was thus somewhat greater in the winter of 1925—26 than in that of 1926—27.

In 1925—26 the 1923 year class constituted 99 per cent. of the haddock examined, in 1926—27 on the other hand only c. 79 per cent.; i. e. a fairly considerable difference.

In 1927 there was only one of the 0-group (year class 1926) amongst the fish analysed, but this group was no doubt more frequent than one might be led to expect from this, since it must be borne in mind that the bulk of the fish of this year class are still so small that they pass through the meshes of the nets used for fishing. Some direct observations show that there were in reality a number of haddock of the 0-group in the Belt Sea in the winter af 1926—27; in October 1926 a number

Table 2. Age and length of haddock caught in the Belt Sea in January, February and March 1927. (The sample from the Samsø Belt not included).

Age group	0	I	II	III	IV	V	?	Total
Year class	1926	1925	1924	1923	1922	1921	?	
cm.								
29	..	1	..	..	..	..	..	1
30	..	1	..	..	..	..	..	1
31	..	2	..	..	..	..	..	2
32	..	1	..	..	..	..	..	1
33	..	1	..	..	..	..	..	1
34	..	..	..	..	..	..	..	..
35	..	1	..	1	..	..	..	2
36	..	..	..	..	..	..	..	..
37	..	..	..	2	..	..	..	2
38	..	..	..	4	..	..	1	5
39	..	..	2	3	..	..	..	5
40	..	..	1	4	..	..	..	5
41	..	..	1	11	..	..	1	13
42	..	..	..	14	..	..	1	15
43	..	..	..	12	..	..	1	13
44	..	..	..	13	..	..	1	14
45	..	..	..	10	..	..	..	10
46	..	..	..	24	1	..	2	27
47	..	..	..	13	..	..	1	14
48	..	..	..	18	..	..	..	18
49	..	..	..	11	2	..	..	13
50	..	..	..	9	3	..	..	12
51	..	..	..	6	1	..	..	7
52	..	..	..	2	1	..	..	3
53	..	..	..	..	..	..	..	..
54	..	..	..	..	2	..	..	2
55	..	..	..	2	1	..	..	3
56	..	..	..	..	..	..	..	..
57	..	..	..	..	..	..	..	..
58	..	..	..	..	..	..	..	..
59	..	..	..	..	..	1	..	1
Total	0	7	4	159	11	1	8	190
Average length in cm...	..	31,6	39,7	45,5	49,1	59,0	..	..

of haddock of the 0-group, 10—15 cm. in length, were observed in the Little Belt, and later in the course of the winter small haddock, about 20 cm. in length, were also seen. We can undoubtedly assume that these haddock of lengths between 10 and 20 cm. belonged to the 0-group; Dr. Johansen namely found by measuring the scales of three-year-old haddock that at the end of their first year these haddock had attained lengths of 11—23 cm.

As shown by Dr. A. C. Johansen, the bulk of the Belt Sea haddock emigrated during the spring of 1926, at the same time as they attained sexual maturity. A

Table 3. Age and length of haddock caught in the Samsø Belt in January 1927.

Age group	0	I	II	III	IV	?	Total
Year class	1926	1925	1924	1923	1922	?	
cm.							
21	1	..	..	..	..	..	1
22	..	..	..	..	..	..	..
23	..	..	..	..	..	..	..
24	..	..	..	..	..	..	..
25	..	..	..	..	..	..	..
26	..	..	..	..	..	..	..
27	..	..	..	..	..	..	..
28	..	..	..	..	..	..	..
29	..	..	..	..	..	..	..
30	..	..	..	..	..	..	..
31	..	3	..	..	..	..	3
32	..	5	..	..	..	..	5
33	..	4	..	..	..	..	4
34	..	7	..	..	..	..	7
35	..	2	..	..	..	..	2
36	..	1	2	..	..	..	3
37	..	1	..	..	..	..	2
38	..	..	..	1	..	..	1
39	..	1	..	2	..	..	3
40	..	..	..	1	..	..	1
41	..	..	..	7	..	..	7
42	..	..	1	3	1	..	5
43	..	..	..	7	..	..	7
44	..	..	1	7	2	..	10
45	..	..	..	9	1	..	10
46	..	..	..	3	..	2	5
47	..	..	..	6	..	..	6
48	..	..	..	5	..	..	5
49	..	..	..	2	..	1	3
50	..	..	..	2	..	..	2
51	..	..	..	5	..	1	6
52	..	..	..	1	..	..	1
53	..	..	..	1	..	..	1
54	..	..	..	1	..	..	1
Total	1	24	4	63	4	4	100
Average length in cm.	21,0	33,5	39,5	45,3	43,7	..	..

stock of immature haddock was thus left behind in the Belt Sea. Analyses of the Belt Sea haddock in the winter and spring of 1927 (Table 4) show that the earliest date for the males to attain maturity is at the end of their second year, and that all males are sexually mature at the end of their fourth year. The case is somewhat different as regards the females. At the end of their second year none of the 18 haddock analysed were sexually mature. Not until the end of their third year (II-group) did any of the females attain sexual maturity. Of III-group and older fish (barely

Table 4. Age, sex and maturity of haddock caught in the Belt Sea in January, February, and March 1927.

Locality	Date	0-Group Year cl. 1926				I-Group Year cl. 1925				II-Group Year cl. 1924				III-Group Year cl. 1923				IV-Group Year cl. 1922				V-Group Year cl. 1921				?	Total
		♂		♀		♂		♀		♂		♀		♂		♀		♂		♀		♂		♀			
		im.	m.	im.	m.	im.	m.	im.	m.	im.	m.	im.	m.	im.	m.	im.	m.	im.	m.	im.	m.	im.	m.	im.	m.		
Langeland Belt	7-I	..	..	..	..	..	..	..	..	..	..	..	..	..	10	..	6	..	..	..	1	..	..	..	1	..	18
East of Samsø.	11-I	1	..	..	..	2	7	15	..	1	1	..	2	..	31	..	32	..	4	..	..	..	..	..	..	4	100
Als Fjord.....	13-I	..	..	..	..	3	..	2	..	..	1	..	3	..	17	..	19	..	1	..	3	..	..	..	..	1	50
North. Gr. Belt	23-I	..	..	..	..	..	..	1	..	..	..	..	..	..	9	..	13	..	..	..	..	..	..	..	..	..	23
North. Little -	8-II	..	..	..	..	..	1	..	..	..	..	..	..	..	27	..	20	..	2	..	4	..	..	..	..	7	61
North. Gr. -	19-II	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	17	..	..	..	..	..	..	..	..	..	22
North. Little -	16-III	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	7	..	..	..	..	..	..	..	..	..	12
Aabenraa Fjord	20-III	..	..	..	..	..	1	..	..	..	..	..	..	..	1	..	2	..	..	..	..	..	..	..	..	..	4
Total...		1	..	..	..	5	9	18	..	1	2	..	5	..	105	..	116	..	7	..	8	..	..	..	1	12	290

four years old and older) were found only sexually mature fish, both male and female. We can thus with some degree of certainty assume that the fish emigrating in the spring of 1926 comprised the bulk of the fish of II-group (year class 1923) together with all the older fish (year classes 1922 and 1921). This means that the stock of haddock which remained behind in the Belt Sea after the emigration consisted mainly of those of the 1923 year class which had not become sexually mature + a small number of younger fish of year class 1925 and perhaps 1924. This means that if immigration had not taken place from outside the stock would have consisted in the following fishing season (the winter of 1926—27) only of year classes 1923 and 1925 and perhaps just a few from 1924. The actual composition of the stock was however, as mentioned, somewhat different. The 1922 year class, which was very poorly represented in the winter of 1925—26, and which may be assumed to have become sexually mature and to have emigrated in the spring of 1926, was present in considerable numbers in the winter of 1926—27 and constituted a much greater percentage of the catch than in 1925—26 (5 per cent. in 1926—27 as against 0,3 per cent. in 1925—26). The 1924 year class which was not represented at all in the analyses from 1925—26 constituted in 1926—27 about 3 per cent. of the fish examined. This change in the stock proves that an immigration of adult fish must have taken place in the course of 1926. The fact that the 1923 year class is less predominant towards the north in the Belt Sea, i. e. in that part where an immigration would first and foremost make itself felt, similarly points to an immigration of adult fish. Analyses of haddock from Samsø Belt (see Table 3) show that the 1923 year class only constituted 66 per cent. in this locality, whereas it constituted 86 per cent. in the more southern part of the Belt Sea.

B. The winter of 1927—28.

In the winter of 1927—28 two samples of haddock from the Belt Sea were examined: one sample of 40 fish caught in the Great Belt to the north of Romsø on January 28th 1928 and one sample of 47 fish caught between Als and Ærø (off Taxensand Lighthouse) on February 7th 1928; the length and age of the haddock examined are given in Table 5.

Table 5. Age and length of haddock caught in the Belt Sea in January and February 1928.

Age group	II	III	IV	V	?	Total
Year class	1925	1924	1923	1922	?	
cm.						
35	1	..	..	..	..	1
36	1	..	..	..	..	1
37	..	..	..	..	..	..
38	..	..	..	..	..	..
39	1	..	..	..	1	2
40	..	1	..	..	..	1
41	2	..	..	..	..	2
42	..	1	..	..	..	1
43	1	..	1	..	..	2
44	..	..	..	..	..	..
45	..	..	1	..	..	1
46	..	1	1	..	..	2
47	..	..	3	..	..	3
48	..	..	6	..	..	6
49	..	1	5	..	..	6
50	..	2	3	..	..	5
51	..	1	9	1	..	11
52	..	..	6	1	..	7
53	..	..	9	1	..	10
54	..	..	4	..	..	4
55	..	..	5	..	..	5
56	..	..	5	..	1	6
57	..	..	1	..	..	1
58	..	..	2	..	..	2
59	..	..	2	1	..	3
60	..	..	1	..	..	1
61	..	..	..	1	..	1
62	..	..	1	..	..	1
63	..	..	..	..	1	1
64	..	..	..	..	..	..
65	..	..	..	1	..	1
Total	6	7	65	6	3	87
Average length in cm.	39,2	46,9	52,2	56,8	..	..

The distribution according to age is calculated for these two samples taken together, and is as follows:

Year class	1925	1924	1923	1922	Total
No. of fish	6	7	65	6	84

It was thus the 1923 year class which was again predominant in 1928; it constituted 77 per cent. of the total number of haddock; i. e. approximately the same as in 1927 (79 per cent.). The 1922, 1924, and 1925 year classes were represented to more or less an equal extent. There were no representatives of the 1926 or 1927 year classes, which is clearly due, so far as the 1927 year class is concerned, to the fish being too small to be caught in large numbers in the nets. It is certain however that they were present since fishermen often noticed small haddock, about 15—20 cm. in length, pouring out of the nets when the latter were drawn up.

A number of small haddock, which nevertheless remained in the nets, were picked out; an analysis shows the following distribution of their size and age.

cm.	Number		cm.	Number	
17	1	0-Group	21	15	0-Group
18	4		22	5	
19	7		23	1	
20	19		24	2	I-Group
			Total	54	

The bulk of them thus belong to the 0-group, i. e. year class 1927, only two belonging to the I-group, i. e. year class 1926. If we compare this analysis with the two other analyses of marketable haddock, we obtain the result that the 1923 year class is completely predominant, year classes 1922, 1924, and 1925 are fairly poor, and year class 1926 very poor whilst the 1927 year class seems to be fairly numerous.

The chief change in the age distribution from 1926—27 to 1927—28 is the addition of an 0-group which under the circumstances is fairly numerous.

4. The growth and nutrition of the haddock in the Belt Sea.

A. C. Johansen[1]) writes of the growth of the Belt Sea haddock during their first three years of life as follows: "The haddock of the Belt Sea have during their first two years of life about the same growth as those of the North Sea, but in their third year, they have grown much faster. The average length of the haddock in the Belt Sea at the close of the first year was about 17 cm., at the close of the second year about 28 cm., and at the close of the third year about 38 cm." In the following we shall consider the growth of the haddock in their fourth and fifth years of life.

In Table 6 a survey is given of the growth of the Belt Sea haddock. It is clear from the table that whereas the mean length of the fish of year class 1923 subjected to examination was 37,6 cm. in the winter of 1925—26, it was 45,4 cm. a year later, and 52 cm. in the following winter of 1927—28. In 1924—25 the mean length according

[1]) loc. cit.

Table 6. The lengths of the year class 1923 of the Belt Sea haddock in different years (1925, 1926, 1927, and 1928).

Length in cm.	April 1925 (after E. Fischer)	Jan.-Febr. 1926 (after A. C. Johansen)	Jan.-March 1927	Jan.-Febr. 1928
25	1	..	..	..
26	1	..	..	..
27	2	..	..	..
28	7	1	..	..
29	17	1	..	..
30	25	1	..	..
31	33	1	..	..
32	20	7	..	..
33	5	12	..	..
34	5	29	..	..
35	2	28	..	..
36	2	44	..	..
37	..	37	2	..
38	1	31	5	..
39	..	27	5	..
40	..	28	5	..
41	..	21	18	..
42	..	12	17	..
43	..	7	19	1
44	..	6	20	..
45	..	5	19	1
46	..	2	27	1
47	..	..	19	3
48	..	1	23	6
49	..	..	13	5
50	..	..	11	3
51	..	..	10	9
52	..	..	4	6
53	..	..	1	9
54	..	..	1	4
55	..	..	2	5
56	..	..	..	5
57	..	..	..	1
58	..	..	..	2
59	..	..	..	2
60	..	..	..	1
61	..	..	..	..
62	..	..	..	1
Total	121	301	221	65
Average length in cm.	30,8	37,6	45,4	52,1

to German investigations was 30,8 cm. These figures can however not be regarded as perfectly correct, for we must bear in mind that the measurements for 1925 do not give a correct impression of the length of year class 1923 from that date, since a number of fish were then too small to be caught in the nets employed;

the sample measured does not thus represent the whole stock owing to the fact that several of the smallest of the year class are lack ng in the calculation. The growth during the first two years is accordingly estimated too high. By means of the calculation of growth made from the scales in the different years, Dr. Johansen found that the length at the end of the first year of life was 16,8 cm., and at the end of the second 27,6 cm., i. e. as might be expected somewhat less than appeared from the results of direct measurements. The growth during the third year of life should thus according to the scale calculations be about 10 cm. and not the 7 cm. indicated by the direct measurements. Although the difference between the lengths found at the end of the third year (37,6) and the end of the fourth year (45,4) is 8 cm. this does not actually give the growth during the intervening year. The samples of year class 1923, which were analysed in 1927 do not show, namely, the growth for the whole stock of this year class which was found in 1926, but only for a fraction of it, viz. that fraction which did not attain sexual maturity in 1926; we can undoubtedly assume that this fraction consisted mainly of the smaller fish, and its average length was therefore somewhat below that which was found for the whole year class (37,6 cm.) The growth in the fourth year of life is therefore somewhat greater than the 8 cm. indicated by the direct measurements. A series of growth determinations carried out by measuring the growth zones in the scales of 18 fish of year class 1923 caught in 1927 give a somewhat different picture as regards growth; they are here tabulated together with Dr. A. C. Johansen's calculations and with the direct measurements.

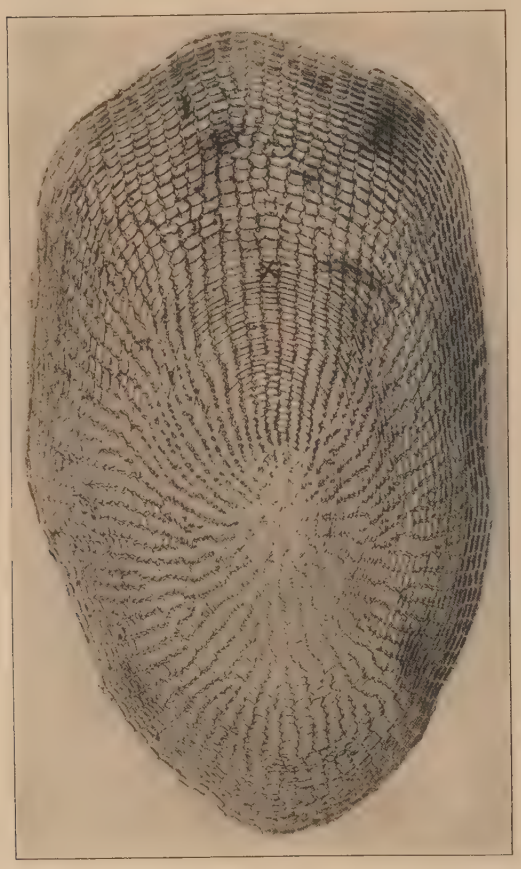

Fig. 2. Scale of haddock of the I-group (nearly 2 years old), female 33 cm., caught east of Samsø, 11. January 1927. The cross is placed where the edge of the scale occurred at the end of the first growth year.

Length at end of	1st	2nd	3rd	4th	5th year of life
Direct measurements .	?	30,8 cm.	37,6 cm.	45,4 cm.	52,2 cm.
Dr. Johansen's calculations in 1926	16,8 cm.	27,6 -	37,6 -	...	...
Author's calculat. 1927	14,6 -	25,5 -	35,6 -	44,7 cm.	...

By using the lengths given above as a basis, we arrive at the approximate growth:

in the 1st year as c. 15,5 cm.
- - 2nd year - - 12,5 -
- - 3rd year - - 9 -
- - 4th year - - 9 -
- - 5th year - - 6,8 -

If we now tabulate these rates of growth for the Belt Sea haddock together with the rates of growth given by Harold Thompson[1]) from other waters, we obtain the following picture of the growth of haddock in the different waters:

	Growth in cm. in 1st year	Length in cm. at end of 1st year	Growth in cm. in 2nd year	Length in cm. at end of 2nd year	Growth in cm. in 3rd year	Length in cm. at end of 3rd year	Growth in cm. in 4th year	Length in cm. at end of 4th year	Growth in cm. in 5th year	Length in cm. at end of 5th year
Iceland	15,1	**15,1**	9,4	**24,5**	9,0	**33,5**	9,5	**43,0**	8,0	**51,0**
South-West Norway.....	17,0	**17,0**	9,0	**26,0**	5,5	**31,5**	8,0	**39,5**	6,5	**46,0**
Dogger Bank.....	17,5	**17,5**	8,5	**26,0**	5,0	**31,0**	7,0	**37,0**	5,2	**42,5**
Jutland Bank.....	17,5	**17,5**	10,5	**28,0**	5,0	**33,0**	4,5	**37,5**	5,0	**42,5**
Fladen.....	17,5	**17,5**	6,0	**23,5**	3,5	**27,0**	4,5	**31,5**	2,5	**34,0**
Skagerak + North. Kattegat	..	..	..	**30,6**	6,3	**36,9**	..	..	..	..
Belt-Sea.....	15,5	**15,5**	12,5	**28,0**	9,0	**37,0**	9,0	**45,4**	6,8	**52,2**

The growth of the Belt Sea haddock has been fairly normal in their first year of life — below normal rather than above it; but from the second year it is above normal and at the end of the fifth year the Belt Sea haddock has attained the very respectable mean length of c. 52 cm.; it has become 1 cm. longer than the Icelandic haddock and 10—18 cm. longer than the haddock from various places in the North Sea. The material from Skagerak and the Northern Kattegat comprises only 57 haddock and these have been taken in catches over a large unequal area; it appears however from the figures that the growth here has been practically as rapid as in the Belt Sea. A sample, not included in the table, of about two-year-old fish caught at Læsø at the end of the winter of 1926 also showed a fairly rapid growth, their mean length (97 fish) being 29,8 cm. A. C. Johansen wrote in 1926 on the growth

[1]) Harold Thompson: Problems in Haddock Biology I. Preliminary Report. Fishery Board for Scotland. Scient. Inv. 1922 No. V.

of haddock in the Belt Sea: "The haddock of the Belt Sea have, during their two first years of life, about the same growth as those of the North Sea, but in their third year they have grown much faster". — "The rapid growth of the haddock of the Belt Sea shows that they have found here particularly favourable conditions of nourishment". A number of examinations of the stomach contents of Belt Sea haddock in 1927 and 1928 compared with examinations of the stomach contents of haddock from the Kattegat, Skagerak, and North Sea show to what a great extent the conditions of nourishment have been favourable for the haddock in the Belt Sea.

Fig. 3. Scale of haddock of the III-group (nearly 4 years old), female 45 cm., caught east of Samsø, 11. January 1927. The crosses are placed where the edge of the scale occurred at the end of the first, second, and third growth year.

In Table 7 a survey is given of the results of the stomach analyses of the Belt Sea haddock. The figures in the first column show within each locality how many of the fish examined had the specified food in their stomachs; the second column gives the corresponding percentage. It is clear from the table that molluscs and echinoderms are the commonest animals in the stomachs, annelids and crustaceans coming next in order; fish are only rarely present. The echinoderms are found in the

greatest quantities in the northern parts of the Belt Sea, being found in 23—67 per cent. of the stomachs, whilst in the more southern parts they are only found in less than 20 per cent. The commonest echinoderm in the stomach contents is *Ophiura albida*; in the most northerly part of the Belt Sea Amphiura are however also frequently found. Echinids are only occasionally found. The most important food for the Belt Sea haddock is however undoubtedly molluscs. Their importance is still greater than is indicated by the table, since they often constituted by far the greatest part of the stomach contents, whereas echinoderms were only found in small numbers. Amongst the molluscs, *Abra alba* completely predominates, *Cultellus pellucidus*, *Macoma baltica*, *Cardium edule*, and *Cylichna alba* being found less frequently. Of annelids, *Nephthys* and *Aphrodite aculeata* occurred very often, *Pectinaria* less often. Amongst the crustaceans, *Crangon allmani*, *Crangon vulgaris*, and *Diastylis ratkei* were predominant; in addition were found Gammeridæ (*Haploops*) and *Mysida* and on a few occasions *Hippolyte* and *Eupagurus bernhardus*. Amongst fishes, *Gobius minutus* was the most common, herring and elvers being found on one occasion.

Fig. 4. Scale of haddock of the IV-group (nearly 5 years old), male 54 cm., caught in Great Belt off Romsø, 28. January 1928. The crosses are placed where the edge of the scale occurred at the end of the first, second, third, and fourth growth year.

For comparison with these analyses of stomach contents from the Belt Sea

Table 7. Food of the Belt Sea haddock.

»*n*« denotes the number of stomachs in which the named food-animals were recorded, »%« denotes the corresponding percentage.

Locality	East of Ballen		Northern Great Belt		Northern Great Belt		Northern Great Belt		Northern Little Belt		Langeland Belt		Als Fjord		Between Als and Ærø		All Localities together	
Date	11-1-1927		23-1-1927		19-2-1927		28-1-1928		8-2-1927		7-1-1927		13-1-1927		7-8-1928		together	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Echinoderma	67	67	8	35	5	23	18	45	1	2	3	18	7	14	9	19	118	33
Mollusca	7	7	16	68	11	50	14	35	24	39	11	61	32	64	21	47	136	38
Crustacea	46	46	4	17	1	5	8	20	5	8	4	22	4	8	1	2	73	20
Annelida	16	16	3	13	2	9	20	50	12	20	7	39	6	12	12	26	78	22
Pisces	4	4	..	..	..	..	..	..	..	..	1	6	2	4	..	..	7	2
No food	12	12	5	22	7	32	10	25	31	51	1	6	16	32	18	38	100	28
Food undetermined	4	4	..	..	..	..	1	3	..	..	5	28	..	..	2	4	12	3
No. of specimens	100	..	23	..	22	..	40	..	61	..	18	..	50	..	47	..	361	..

we have some analyses from the Kattegat and Skagerak, and also some analyses from the eastern part of the North Sea. The stomach contents of 27 haddock from the northern Kattegat were analysed on April 30th 1926; these belonged mainly to the II- and III-groups and were caught at Læsø Trindel at a depth of 43 metres. By far the greatest part of the stomach contents consisted here of *Cardium suecicum*, this being found in 26 of the 27 stomachs. Crustaceans were found in 5 stomachs, whilst echinoderms (a single *Echinocardium cordatum*) were only present in one stomach.

H. Blegvad[1]) examined some years ago 35 haddock from the Kattegat (no closer description of the locality) which had principally eaten Amphiura (*Amphiura chiajei* and *A. filiformis*); in their stomachs were also found *Ophiopholis aculeata*, *Gammarides*, *Mysis*, *Crangon*, and *Nereis*.

From the Skagerak, 73 fish have been examined which were caught at depths between 60 and 180 metres in April 1926[2]) belonging for the most part to the I-, II-, and III-groups. The bulk of the stomach contents consisted of *Meganyctiphanes norvegica*. Molluscs were found in considerably smaller quantities (*Cardium suecicum*, *Yoldia lucida*, *Leda minuta*, *Cylichna alba*, and *C. cylindracea*).

Very comprehensive examinations have been made of haddock caught by fishermen in the North Sea and more especially on Jutland Bank during the months August—December in 1924, 1925, 1926, and 1927. In this case the stomachs have not been examined singly, but samples consisting of about 6 stomachs have been examined. Altogether c. 450 samples have been subjected to examination. For each

[1]) H. Blegvad: On the Food of Fish in the Danish Waters within the Skaw. Report XVI from the Danish Biological Station. 1916.

[2]) Erik M. Poulsen: Om den store Lyskrebs' (*Meganyctiphanes norvegica*) Betydning som Fiskeføde i Skagerak. Dansk Fiskeritidende, 1926.

sample the approximate percentage of the most important groups of food animals (echinoderms, annelids, crustaceans, and molluscs) has been calculated[1]).

It appears from these investigations that echinoderms (especially *Amphiura filiformis* and *A. chiajei*) are of particular importance as food for the haddock in the North Sea; similar observations have been made by Todd[2]) and H. Blegvad[3]). Of considerable less importance are the annelids, crustaceans, and molluscs, whilst fish here as in the other localities investigated are of very little importance. Of the molluscs, *Cultellus pellucidus* is particularly common in the stomachs and in addition *Cylichna-* and *Montacuta*-species together with several other molluscs are fairly frequent. Among the crustaceans, *Crangon allmani*, *Portunus* species, *Gastrosaccus spinifer* and various amphipods predominate. Altogether echinoderms may be said to constitute the chief food of the North Sea haddock from Jutland Bank.

These investigations of the stomach contents of haddock, which have been made throughout the various Danish waters from the North Sea to the western Baltic, show that the food of the haddock varies greatly; at medium depths in the North Sea, where there is a dense stock of Amphiura, the haddock gorges itself on these animals which provide little nourishment in proportion to their quantity. In the deeper Skagerak, where the haddock encounters large swarms of *Meganyctiphanes norvegica*, it feeds on this fat crustacean to the practical exclusion of anything else. In the northern Kattegat the Amphiura together with the molluscs constitute the chief food of the haddock. In the Belt Sea and the western Baltic the echinoderms are only of slight importance considered as food, their place being taken by molluscs, crustaceans, and annelids. There can be no doubt that these three groups of animals constitute a far more nourishing food than the calcareous echinoderms, and there is thus every reason to suppose that it is in fact this more nourishing food which causes the rapid growth of the Belt Sea haddock. In this connection it is of interest to notice that in the Skagerak and the northern Kattegat, where the importance of echinoderms as food for the haddock is considerably lessened whilst that of crustaceans and molluscs correspondingly increases, the growth of the haddock may be assumed, according to the measurements given in the table p. 113, to be considerably greater than in the North Sea, and perhaps approximately as great as in the Belt Sea.

5. Propagation of the Belt Sea haddock.

It is of course a question of the greatest significance for the coming years' haddock fishery in the Belt Sea to what extent the haddock immigrating into this Sea will propagate there.

The salinity of the Belt Sea even in the deeper water is considerably lower

[1]) Erik M. Poulsen: Om Kullerens Føde i Nordsøen. Dansk Fiskeritidende, 1926.

[2]) R. A. Todd: Second Report of the Food of Fishes. Marine Biological Association of the United Kingdom, International Fishery Investigations. Second Report (Southern Area), Part I, 1904—1905.

[3]) loc. cit.

than the lowest salinity known in the spawning places of haddock. The haddock is a pronounced salt water fish which has never been observed to spawn in water of lower salinity than about 33—34 per mille; water of this salinity does not penetrate further into Danish waters during the haddock's spawning season in the early spring than the northern part of the Kattegat. Only in certain years when there is an unusually strong inflow of salt water (e. g. in the spring of 1923) does water of such great salinity penetrate further down into the southern Kattegat.

A. C. Johansen (1926) assumed that the haddock which attained maturity in the spring of 1926 emigrated from the Belt Sea, and in fact no haddock larvae were found in the Belt Sea during that spring at the investigations carried out by the Danish Biological Station; nor was it found possible to hatch haddock larvae from eggs of the genus *Gadus* which had been collected, although cod larvae were hatched. There is therefore every reason to suppose that no haddock larvae developed in the Belt Sea in the spring of 1926. A. C. Johansen writes as follows on the stage of maturity of the haddock examined in January-February 1926: "We find for instance, that the genital organs in these three year old fish were, in January and February far less developed than is normally the case at the season in question, among adult haddock in the North Sea and Skagerak. Out of a sample of 80 specimens from Aabenraa Fjord from the end of January, 71 were due to spawn in the spring of 1926, but the eggs were quite small only about 0,2—0,3 mm., and the testes as yet but slightly swollen. It looked then, as if these fish would not spawn before April or May, whereas the haddock of the Skagerak have their main spawning season in March".

In the winter and spring of 1927 the stage of maturity of the Belt Sea haddock was however somewhat different. Table 8 shows the size of the eggs of the mature haddock in the winter and spring of 1927:

Table 8. Size of eggs of mature haddock from the Belt Sea in the winter and spring of 1927.

Date	$^{7}/_{1}$	$^{11}/_{1}$	$^{13}/_{1}$	$^{23}/_{1}$	$^{8}/_{2}$	$^{19}/_{2}$	$^{16}/_{3}$
Number of females with eggs of averagely 0,3 mm.	1	..	1	..	..	..	..
» » » » » » » 0,4 »	1	7	3	..	..	..	..
» » » » » » » 0,5 »	..	7	10	4	1	..	..
» » » » » » » 0,6 »	4	10	7	6	1	..	..
» » » » » » » 0,7 »	2	7	4	3	14	2	..
» » » » » » » 0,8 »	..	2	..	..	..	1	..
» » » » translucent eggs	..	2	..	..	8	14	·7
Number of mature females...	8	35	25	13	24	17	7

Whilst the fish caught in Aabenraa Fjord at the end of January 1926 only possessed eggs 0,2—0,3 mm. in diameter, the diameter of the eggs in the same locality

and at the same time of year 1927 were on an average a little over 0,5 mm., varying from 0,3 mm. to 0,7 mm. In Samsø Belt a few of the females examined possessed translucent eggs already on January 11th. Amongst the fish caught in Little Belt and Great Belt in the middle of February rather more than half of the sexually mature females possessed translucent eggs, whilst in the middle of March all the sexually ripe females investigated possessed translucent eggs and running roe; the testes of the males were simultaneously much swollen and to some extent with running milt.

No spent specimens were among the few fish which we submitted to examination at the end of March, but we have received information that fishermen have caught spent haddock at the end of March between Als and Ærø. Since females with running roe, males with running milt, and spent fish have thus all been found in the Belt Sea in the spring of 1927, there is no doubt that the haddock became sexually mature in the Belt Sea in the spring of 1927 and spawned there, i. e. in water of about 21—23 ‰ salinity.

In order to ascertain to what extent the eggs spawned in the Belt Sea had developed into larvae, fishing experiments with ring trawl and young-fish trawl were carried out in the Belt Sea by the Danish Biological Station in March and April 1927. These fishing experiments gave a completely negative result as regards the presence of haddock larvae; these were nowhere found although many cod larvae were present in the hauls. The hatching out of some eggs of *Gadus* collected at the end of March produced no haddock larvae, only cod larvae.

The haddock has thus doubtlessly spawned in the Belt Sea in the spring of 1927, but no — or almost no — larvae have developed from the eggs spawned.

The haddock has also spawned in the Belt Sea in the spring of 1928. The following stages of maturity were found by investigations at the end of January and the beginning of February 1928:

40	fish	were of maturity	IV (eggs c. 0,4 mm. in diameter)
28	—	—	V (— - 0,7 - —)
9	—	—	VI (running roe and milt).

Fishermen have also in 1928 noticed spent haddock in the Belt Sea.

As regards the spawning of haddock in the Belt Sea the following facts are thus known to us. No evidence of ripe haddock was found in the Belt Sea in the spring of 1926; the mature fish seem to have left these waters before spawning; in 1927 and 1928 the mature fish — or in any case a number of them — remained in the Belt Sea and spawned there, but no larvae, at any rate in 1927, developed from the eggs. Nor did the fishing experiments with ring trawl in May bring to light any tiny haddock larvae in the northern part of the Belt Sea in the spring of 1928. It

can thus be undoubtedly regarded as established that the haddock can certainly develop ripe eggs and milt in the comparatively low salinity of the Belt Sea water; it is however also established that, as a rule in any case, no larvae develop from the eggs spawned.

The appreciable numbers of the 0-group of the haddock which were observed during fishing operations in the Belt Sea in the winter of 1926—27 and especially in the winter of 1927—28 must have originated from outside these waters; it is thus not in the spring (when the presence of tiny larvae has not been proved) but later in the year that an immigration of haddock into the Belt Sea took place. It is a well-known fact that a considerable immigration of haddock from the Skagerak to the northern and eastern Kattegat takes place in the course of the autumn months; it is therefore probable that these haddock of the 0-group have come in with this immigration, and that the latter to some degree has extended to the Belt Sea; that haddock of older year classes have also come in with this immigration is proved by the fact that the stock, as mentioned p. 108, was more mixed as regards its year classes in the winters of 1926—27 and 1927—28 than in the winter of 1925—26.

In June 1928 a series of fishing experiments with ring trawl was carried out in the Belt Sea and the southern Kattegat by the Danish Biological Station. Very few haddock larvae were caught at these experiments:

June 9th 1928. $1^1/_2$ miles S.t.W. of Halskov Reef Lightship (Great Belt) 45 m., ring trawl 100 m. wire, $^1/_4$ hour: 1 haddock larva 16 mm.

June 18th — 1 mile E. of Hov Lighthouse (Langeland Belt) 34 m. ring trawl $^1/_2$ hour: 1 haddock larva 21 mm.

June 21st — $5^1/_2$ miles N.N.W. of Refsnæs Lighthouse (northern Great Belt) 37 m., ring trawl 70 m. wire, $^1/_2$ hour: 1 haddock larva 24 mm.

Altogether 18 stations, from which the ring trawl was used, were taken in the Belt Sea; at these 18 stations 3 haddock larvae were thus caught, but they had probably been carried into the Belt Sea by the bottom current flowing south from the Skagerak and Kattegat. A series of observations of the salinity show that in this very month of June a strong inflow of salt water occurred:

Stat. 909, Great Belt, 55°18′50″ N. Lat. 11°02′20″ E. Long. June 18th 1928.
20 m. 28,33 ‰, c. 0 ‰ above normal.
25 m. 30,91 ‰, c. 1—2 ‰ above normal.
45 m. 31,55 ‰, c. 2—3 ‰ — —

Stat. 938, Northern Langeland Belt, 55°00′50″ N. Lat. 11°01′40″ E. Long. June 18th 1928.
21 m. 26,62 ‰, c. 4—5 ‰ above normal.
25 m. 31,26 ‰, c. 6—8 ‰ — —
29 m. 33,56 ‰, c. 5—6 ‰ — —

Stat. 939, Northern Langeland Belt, 55°08′55″ N. Lat. 10°59′30″ E. Long. June 18th 1928.

20 m. 26,47 ‰, c. 4 ‰ above normal.
25 m. 30,70 ‰, c. 5—6 ‰ above normal.
28 m. 31,13 ‰, c. 2—3 ‰ — —
33 m. 31,35 ‰, c. 2 ‰ above normal.

That fewer larvae were carried along with this inflow than in the spring of 1923 is due to the fact that, whereas 1923 was a favourable year for the spawning of the haddock in the northern Kattegat, 1928 has been unfavourable, as is shown by the following fishing experiments, carried out in May and June.

	1923	1928
North of Læsø.....	at 5 stations av. 6 haddock larvae	at 1 stations 0 haddock larvae
East of Hals.....	- 2 — - 9 —	- 1 — 0 —
North of Djursland.....	- 2 — - 44 —	- 1 — 1 —

The number of haddock larvae in the Kattegat was thus far smaller in 1928 than in 1923, for which reason fewer larvae accordingly entered the Belt Sea with the salt water in 1928 than in 1923; nevertheless we may assume that the haddock larvae brought into the Belt Sea in 1928 will have some influence on the size of the haddock stock there in the coming years.

The 0-group of the haddock has also been observed in the western Baltic in the later part of the year. At fishing experiments with eeltog (a fine meshed otter seine) at the end of July, 3 haddock of the 0-group were caught in all at 3 stations in the deeper parts of the Western Baltic. In the following reports from the stations are included, in addition to haddock, other codfish caught there.

Stat. 1111. July 24th 1928. Aabenraa Deep, 55°04′12″ N. Lat. 9°57′54″ E. Long. Depth 31 m., fishing gear: eeltog, duration of haul: ½ hour.

1 haddock 0-group 80 mm.
14 cod 0-group 5—7 cm.
4 cod I-group 15—17 cm.
12 whiting 0-group 6—8 cm.
2 whiting I-group 15—16 cm.

Stat. 1112. July 25th 1928. Aabenraa Fjord, 55°02′24″ N. Lat. 9°31′15″ E. Long. Depth 30—32 m., fishing gear: eeltog, duration of haul: ½ hour.

1 haddock 0-group 89 mm.
11 cod I-group 13—18 cm.
35 whiting 0-group 5—9 cm.
2 whiting I-group 17—21 cm.

Stat. 1122. July 27th 1928. Between Als and Ærø, 55°51′ N. Lat. 10°09′12″ E. Long.
Depth 32 m., fishing gear: eeltog, duration of haul: ½ hour.
1 haddock 0-group 72 mm.
2 cod I-group 13—17 cm.
1 cod VII-group 77 cm.
3 whiting 0-group 7—7—7 cm.

In the northern part of the Belt Sea haddock of the 0-group were caught at 4 stations:

Stat. 1139. July 31st 1928. North of Fyen, 55°46′30″ N. Lat., 10°5′55″ E. Long.
Depth 14 m., fishing gear: eeltog, duration of haul: ½ hour.
3 haddock 0-group 78, 85, 91 mm.
9 cod 0-group 6—8 cm.
18 cod I-group 11—15 cm.
9 whiting 0-group 6—8 cm.

Stat. 1142. August 1st 1928. Northwest of Samsø, 56°4′30″ N. Lat., 10°25′40″ E. L.
Depth 24 m., fishing gear: eeltog, duration of haul: ½ hour.
1 haddock 0-group 94 mm.
4 cod 0-group 7—10 cm.

Stat. 1144. August 1st 1928. Kalø Vig, 56°12′40″ N. Lat., 10°19′55″ E. Long.
Depth 20 m., fishing gear: eeltog, duration of haul: 10 min.
1 haddock 0-group 68 mm.
5 cod 0-group 7—10 cm.
4 cod 0-group 15—17 cm.

Stat. 1156. August 4th 1928. North of Sejrø, 55°59′ N. Lat., 11°3′ E. Long.
Depth 26 m., fishing gear: eeltog, duration of haul: ½ hour.
1 haddock 0-group 75 mm.
71 cod 0-group 5—12 cm.
5 cod I-group 14—25 cm.

At the fishing experiments with eeltog in the Great Belt at the end of July no haddock were caught, either in the shallower or the deeper water. Nor were haddock caught at 3 stations to the south of Langeland. In the waters between South Jutland, Als and Ærø fishing experiments have been carried out in July 1928 at 14 stations in all, and only at three of these, as shown, have haddock of the 0-group been observed. All these three stations are situated in water of 30—32 metres' depth. At the stations in shal ower water haddock have thus not been caught, although on the other hand cod and whiting have been caught. It thus seems as if the haddock only occurs in the Western Baltic in the deeper localities to the north and east of Als. The number of haddock of the 0-group is extremely small in comparison with the numbers of

cod and whiting of the 0-group. Haddock of the I-group were not observed at all at these fishing experiments, whereas on the other hand several cod and whiting of the I-group were caught.

It has been shown in the foregoing that the haddock larvae caught in June in the Belt Sea had entered the latter simultaneously with a strong inflow of salt water which by the middle of June had penetrated as far south as the northern part of Langeland Belt. A series of observations carried on in the Western Baltic at the end of July shows that the salt water now had penetrated right down to the waters between Funen and South Jutland. In the following will be found some observations made in June and July from these waters together with particulars as to how much the salinities recorded exceed the normal salinities calculated on the basis of observations made by E. Ruppin[1]) and J. P. Jacobsen[2]):

S.E. of Pøls Huk. Stat. 933 June 14th; Stat. 1122 July 27th; c. 30 m.

Depth	June 14th	Depth	July 27th	above or below normal June 14th	above or below normal July 27th
0 m.	14,9 ‰	0 m.	19,3 ‰	c. 1 ‰ above	c. 5 ‰ above
10 m.	16,3 ‰	10 m.	20,0 ‰	c. 1 ‰ -	c. 4 ‰ -
20 m.	20,1 ‰	20 m.	21,9 ‰	c. 1 ‰ -	c. 3 ‰ -
24 m.	22,3 ‰	25 m.	23,3 ‰	c. 2 ‰ -	c. 3 ‰ -
27 m.	23,1 ‰	31 m.	24,4 ‰		

Aabenraa Fjord, Stat. 920 June 12th; Stat. 1113 July 25th; c. 33 m.

Depth	June 12th	Depth	July 25th	above or below normal June 12th	above or below normal July 25th
0 m.	17,1 ‰	0 m.	21,2 ‰	c. 1 ‰ above	c. 5 ‰ above
20 m.	19,6 ‰	20 m.	23,5 ‰	c. normal	c. 4 ‰ -
25 m.	20,1 ‰	26 m.	24,5 ‰	—	c. 4 ‰ -
33 m.	23,0 ‰	34 m.	26,7 ‰	—	c. 4 ‰ -

Aabenraa Deep, Stat. 924 June 12th; Stat. 1111 July 24th; c. 30 m.

Depth	June 12th	Depth	July 24th	above or below normal June 12th	above or below normal July 24th
0 m.	17,1 ‰	0 m.	21,5 ‰	c. 1 ‰ below	c. 3 ‰ above
20 m.	19,5 ‰	20 m.	24,0 ‰	c. normal	c. 4 ‰ -
28 m.	21,0 ‰	30 m.	27,3 ‰	c. 1 ‰ above	c. 4 ‰ -

Whilst the salinity in June in the western Baltic was approximately normal, it had increased in July to about 3—5 per cent. above the normal both as regards

[1]) Ernst Ruppin: Beiträge zur Hydrographie der Belt- und Ostsee. Intern. Meeresforschung, Kfel, Hydrographische Abt. No. 10.

[2]) J. P. Jacobsen: Mittelwerte von Temperatur und Salzgehalt bearbeitet nach hydrographischen Beobachtungen in dänischen Gewässern 1880—1907. Meddelelser fra Kommissionen for Havundersøgelser, Serie Hydrografi, No. 10. 1908.

the surface and the bottom water. Since no haddock larvae were observed in the Western Baltic at the fishing experiments in June when the salinity was normal but were found in July on the other hand when the salinity was abnormally high, it may be regarded as established that the 0-group of the haddock had entered the Western Baltic at the end of June or during July.

The immigration of the 0-group of the haddock into the Belt Sea and the Western Baltic in 1928 thus took place as follows: the hydrographical conditions in the Belt Sea and the Western Baltic were still normal in May, but in the southern Kattegat at Schultz' Ground the salinity was somewhat above normal; at fishing experiments in the Belt Sea and the Western Baltic no haddock larvae were found in this month. In June the salt water had penetrated as far south as to the middle of Langeland Belt; just a few haddock larvae were then found as far south as the deep water in the northern part of Langeland Belt. At the end of July the salt water had entered the Western Baltic and had penetrated right into the deep of Aabenraa Fjord; haddock of the 0-group simultaneously appeared to the north and east of Als and in Aabenraa Fjord.

In estimating the chances of a future haddock fishery in the Belt Sea, the following facts based on the experience obtained during the years 1923—28 can be regarded as established, 1) that haddock do not propagate in the Belt Sea, or at any rate only in quite exceptional cases, and that an indigenous stock of haddock will thus not be formed in the course of years, 2) that on the other hand haddock right from the larval stage can live and thrive in the Belt Sea quite as well as in any other waters. The haddock stock in the Belt Sea can thus only be maintained by a supply of larvae or older haddock from outside, i. e. from the Kattegat and Skagerak. Such a supply takes place in those few years when an especially strong inflow of salt water occurs, and particularly when this inflow occurs directly after the haddock's spawning season in the spring and early summer. The investigations undertaken indicate that in the next few years it will be possible to carry on a haddock fishery in the Belt Sea and Western Baltic to a certain extent. As shown in the foregoing, there are fairly considerable numbers of one-year-old haddock in these two areas, and haddock larvae have moreover streamed in during the early summer of 1928.

Since quite specific natural conditions are required for the Belt Sea to be provided with haddock larvae to any appreciable extent, the haddock fishery in the Belt Sea must be regarded in the future as subjected to very considerable fluctuations, and it will undoubtedly for periods of long duration — as prior to 1925 — be of exceedingly small importance.

Since haddock have proved to thrive to an even remarkable degree in the Belt Sea, it is probable that by putting out of artificially hatched haddock larvae in the Belt Sea[1]) it would be possible to form the basis of an important haddock fishery

[1]) See A. C. Johansen 1926 loc. cit.

in these waters. At a time when the prosperity of the Belt Sea fishery is severely threatened by the constant diminution of the plaice stock, there is an especial reason for investigating the possibility of establishing, by hatching and putting out haddock larvae, a fishery which might afford some compensation for the declining plaice fishery.

We here lack an experimental station for the furtherance of such operations or of similar projects such as the hatching of lobsters, the feeding of plaice in captivity, etc.

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